

**THE ANATOMY OF THE BLOOD SUPPLY OF PENILE SKIN
AND ITS RELEVANCE TO RECONSTRUCTIVE SURGERY OF THE
LOWER URINARY AND GENITAL
TRACTS**

BY

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- (a) This Thesis has been entirely composed by myself.
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- (c) I have not submitted the thesis in candidature for any other degree, diploma or professional qualification.

JOHN KWATEBOI MARMON QUARTEY
September 1992..

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CONTENTS**PAGE**

ACKNOWLEDGEMENTS	2
ABSTRACT	9
SUMMARY	11
CHAPTER 1								
INTRODUCTION	17
CHAPTER 2								
MATERIALS AND METHODS	...	...	...	...	...	...	...	28
(1)	First dissection.	...	...	...	...	...	...	29
(2)	Second dissection.	...	...	...	...	...	...	29
(3)	Gross dissection in fresh cadavers.							30
(4)	Gross dissections in embalmed cadavers after intra-arterial injection of latex or microfil.	...	...	...	...	...	...	30
(5)	Microscopal examinations of cross-sections of prepuce.	...	...	...	...	...	...	33
(6)	Macroscopic and microscopic examinations of cross-sections of penile shaft.	...	...	...	...	...	...	33
(7)	Penile-preputial island skin flap urethroplasty.	...	...	...	...	...	...	34
(8)	Superficial venous drainage of penis.							34
(9)	Clitoral island skin flap vulvo-vaginoplasty.	...	...	...	...	...	...	34
CHAPTER 3								
RESULTS AND OBSERVATIONS	...	...	...	...	...	...	...	35

CHAPTER 4

ARTERIAL BLOOD SUPPLY OF THE COVERINGS OF THE PENIS	40
Superficial (Superior) External Pudendal Artery	40
Deep (Inferior) External Pudendal Artery	... 43
The Subdermal (Subdartos) Arterial Plexus	... 48

CHAPTER 5

VENOUS DRAINAGE OF THE COVERINGS OF THE PENIS	... 51
Subdermal (Subdartos) Plexus of Veins	... 51
Large Independent Veins (Communicating Veins)	... 53
Venae Comitantes	... 60
Random Veins	... 61

CHAPTER 6

LAYERS OF THE COVERINGS OF THE PENIS	... 63
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CHAPTER 7

TRANSVERSE DISTAL PENILE/PREPUTIAL

ISLAND SKIN FLAP URETHROPLASTY FOR STRICTURE	... 67
(i) Technique	
(a) Patch Urethroplasty	... 67
(b) Tube Urethroplasty	... 75
(ii) Results	... 82
(iii) Complications	... 82
(a) Fistula Formation	... 82
(b) Stenosis and Restricture	... 83
(c) Superficial necrosis of denuded skin flap	... 83
(d) Diverticulum Formation	... 85

CHAPTER 8

CLITORAL ISLAND SKIN FLAP VULVO-VAGINOPLASTY IN

FEMALE PSEUDO-HERMAPHRODITES OF THE ADRENOGENITAL

SYNDROME	...	...	...	...	...	...	...	...	...	86
(i)	Technique	...	...	...	...	...	...	...	...	87
(ii)	Results	...	...	...	...	...	...	...	...	96

CHAPTER 9

DISCUSSION	...	...	...	...	...	...	...	...	97
Arterial Supply	...	...	...	...	...	...	...	...	97
Venous Drainage	...	...	...	...	...	...	...	...	105
Full Thickness Skin Grafts	...	...	...	...	...	...	...	...	107
Skin Flaps	...	...	...	...	...	...	...	...	108
Coverings of the Penis	...	...	...	...	...	...	...	...	108
Complications of Substitution Urethroplasty	...	...	...	...	...	...	...	...	114
1. Fistula formation	...	...	...	...	...	...	...	...	115
2. Stenosis and restricturing at the anastomotic sites	...	...	...	...	...	...	...	...	115
3. Stenosis and restricture proximal to the proximal membranous urethro-cutaneous anastomosis	...	...	...	...	...	...	...	...	116
4. Diverticulum formation	...	...	...	...	...	...	...	...	118
Clitoral Island Skin Flap Vulvo-Vaginoplasty	...	...	...	...	...	...	...	...	118

CHAPTER 10

CONCLUSIONS	...	...	...	...	...	...	...	...	120
REFERENCES	...	...	...	...	...	...	...	...	123

ABSTRACT

In 1981, proposed use of distal hairless peno-preputial skin for urethroplasty prompted a search of the anatomy literature for the pattern of the blood supply of the coverings of the penis. An axial pattern arterial supply would most favourably support such a distal island of skin. There was no such detail in all the standard English Anatomy, Applied Anatomy and Micro-anatomy texts consulted. This work was therefore undertaken to establish the anatomical basis for such distal peno-preputial island flap urethroplasty, and as it turned out, help fill this small gap in the anatomy literature.

The arterial blood supply of the coverings of the penis is derived from the superficial and deep external pudendal branches of the femoral arteries, passing medially to end as dorsolateral and ventrolateral axial branches, running in the loose areolar subdartos (subcutaneous) tissue along the shaft to the glans and prepuce. Branches connecting the axial, help form a subdartos (subcutaneous) arterial network, from which fine branches pass superficially to join the subdermal (subdartos) plexus nourishing the skin and dartos unit, and deeply to join the deep plexus formed by the dorsal arteries and their circumflex branches, lying between the fascia penis and tunica albuginea of the corpora

cavernosa and spongiosum.

Venae comitantes of the axial arteries, and large superficial dorsal median and lateral veins in the loose subdartos (subcutaneous) tissue, drain the coverings of the penis via the superficial external pudendal vein, into the long saphenous, just before it terminates in the femoral.

The skin with dartos muscle and subdermal (subdartos) plexus of blood vessels, can be easily separated from the loose vascular subdartos (subcutaneous) tissue, which in turn can be separated from the (Buck's) fascia penis, enabling the formation of a distal peno-preputial "hairless" skin island with a subcutaneous vascular pedicle for urethral reconstruction in the male, and vaginal reconstruction in the female with hypertrophied clitoris.

More than 100 of the distal peno-preputial skin island urethroplasties for strictures of all parts of the urethra, and 2 vulvo-vaginoplasties for female pseudohermaphrodites of the adrenogenital syndrome have been successfully done since 1981.

SUMMARY

A study of the blood supply of the coverings of the penis as a basis for a distal penile-preputial island flap urethroplasty was undertaken.

The history of various techniques of urethroplasty for hypospadias and urethral stricture over the past 150 years is reviewed.

The paucity of details of the pattern of distribution of the arteries to the coverings of the penis in the anatomic literature is noted, and reviewed.

Dissections of the femoral triangle and penis were carried out in fresh and embalmed cadavers, with and without injection of coloured latex or silicone rubber into the femoral-external pudendal arteries system.

Observations were also made of the blood supply in live patients, and at the operations of distal peno-preputial island flap urethroplasty for hypospadias and urethral stricture, and vulvo-vaginoplasty in female pseudo-hermaphrodites with hypertrophied clitoris.

Arterial Supply

The arterial blood supply of the coverings of the penis

is derived from the superficial (superior) and deep (inferior) external pudendal arteries, branches which, arising from the first part of the femoral artery, run medially to the base of the penis. There, they end as dorso-lateral and ventro-lateral axial branches which run in the loose subcutaneous tissues towards the glans and prepuce.

The axial branch arteries divide and reanastomose, and are connected together by cross branches to form a superficial network, from which fine branches at intervals along the shaft of the penis, pass superficially to join the subdermal or subdartos plexus of blood vessels, which nourishes the skin and dartos, and deeply to join the deep plexus of blood vessels through the fascia penis (Buck's fascia).

The main supply of the subdermal or subdartos arterial plexus is derived from branches of the axial arteries which are given off at or near the base of the penis. Only fine additional arterial branches supplement this source along the shaft of the penis.

The main connections between the superficial arterial plexus and the deep arterial plexus formed by the dorsal arteries and their circumflex branches, are perforators

which are found behind the coronal sulcus. Along the shaft of the penis, only fine branches pass between the two plexuses.

The axial arteries, after giving off the perforators behind the coronal sulcus, run between the two layers to the tip of the prepuce.

Venous Drainage

The venous drainage of the coverings of the penis, consists of venae comitantes of the axial arteries, small random veins, and large independent veins, most commonly the superficial dorsal median vein or veins, but frequently in addition, dorso-lateral or lateral veins, and occasionally ventro-lateral veins.

Layers of the Coverings of the Penis

From outside inwards, along the shaft, the layers of the coverings of the penis consist of;

The skin resting on a layer of smooth muscle or dartos, and together with the subdermal (subdartos) plexus of blood vessels forming a closely knit unit.

Next is the layer of loose areolar "subcutaneous" tissue containing the superficial plexus of blood vessels or what might be termed more accurately the intermediate

plexus.

Then comes the elastic layer called the fascia penis or Buck's fascia, which ensheaths the corpora cavernosa and corpus spongiosum, and separates the intermediate, and deep vascular plexus of dorsal and circumflex vessels.

Deep to the deep vascular plexus is the tunica albuginea surrounding the erectile tissues of the corpora cavernosa, and the corpus spongiosum enclosing the urethra ventrally.

There is a definite plane of cleavage between the skin, dartos and subdartos vascular plexus unit, and the loose subcutaneous areolar tissue containing the intermediate vascular plexus, making for their easy separation, and also between the subcutaneous (subdartos) unit and the fascia penis, which makes it possible to isolate an island of preputial (inner, outer or double faced), or distal penile skin in the circumcised, on a loose areolar vascular pedicle, for urethroplasty.

The same anatomical layers and vascular pattern are to a great extent present in the female clitoris, and an island of the complete skin of the hypertrophied clitoris can be used to reconstruct the vulva and distal portion of the vagina and the introitus, in feminizing

genitoplasty, for female pseudo-hermaphrodites of the adrenogenital syndrome.

Distal peno-preputial skin flaps for urethroplasty has been performed in over 100 patients for hypospadias and urethral stricture in males. in males.

The complete clitoral skin flap for vulvo-vaginoplasty in female pseudo-hermapherodites has also been performed in 2 patients.

So far survival of these skin flaps has been 100%.

There have been complications of stenosis and restructure at anastomotic sites between flap skin and urethral mucosa in some urethroplasties, for both hypospadias and urethral stricture. This is ascribed to operative technical faults in not achieving accurate skin to mucosa apposition in suturing.

Superficial necrosis of the skin of the distal frenal area of the denuded skin-dartos unit has sometimes occurred. This is explained by inadequate vascularity at the distalmost area, because the main arterial branches supplying the subdermal (subdartos) arterial plexus, are given off from the axial arteries at the base of the penis. Dissection too close to the skin while isolating

the vascular pedicle, also destroys parts of the plexus.

Diverticulum formation of the peno-preputial skin in the area of reconstruction occurs in a variable proportion of urethroplasties, and is generally explained by the use of too large a piece of skin.

There has been no stenosis of the introitus of the two vaginoplasties done, and the depth of the vagina has been adequate.

CHAPTER 1

INTRODUCTION

History of the development of urethroplasty

Congenital anomalies of the lower urinary and genital tracts, such as hypospadias, epispadias and exstrophy complex, cloacal abnormalities, trauma to the urethra, and urethral stricture, most commonly the result of gonorrhoea, and intrsex, have been the challenges and stimuli for the development of techniques for reconstruction of the urethra and the external genitalia.

Many structures and tissues have been tried as substitutes for the replacement and reconstruction of the urethra, such as the appendix (Axhausen - 1918, McGuire - 1927), vein grafts (Cantas - 1911), bladder mucosal grafts (Mummelaar - 1947, Marshall and Spellman - 1955), tunica vaginalis (Kishev - 1960), split thickness skin (Nove-Josserand - 1897, McIndoe - 1937), but none has proved as successful and reliable as full thickness skin, either as a graft (Presman, and Greenfield - 1953, Devine and Horton - 1961), or as a flap, (Byars - 1955, Broadbent et. al. - 1961, Des Prez et. al. 1961, Hodgson - 1970, Asopa - 1971, Hinderer - 1975, Standoli - 1977, Duckett - 1980, Quartey - 1983).

The skin of the penis and prepuce has been used for reconstruction of the urethra for over a century and a half, but mainly as local flaps for the repair of adjacent defects.

Duplay I (1874), Broadbent et.al. (1961), Mustarde (1965), Hinderer (1968), Des Prez et.al. (1961), and others used longitudinal ventral or oblique ventro-lateral skin flaps in continuity with the hypospadiac meatus to form the new urethra.

Duplay II (1880), Hamilton Russell (1914-15), and Denis Browne (1949) used the buried skin strip principle with marginal epithelialisation for reconstruction of the urethra in hypospadias, and the principle was adapted by Johanson (1953) in the two-stage reconstruction of the urethra in impassable strictures.

Davis (1950), for hypospadias, made the distal urethra with a dorsal penile skin flap which was proximally based and commented:

"Consideration of the vascular system of the penis made it apparent that the arteries supplying blood to the prepuce were on the dorsal surface near the midline, and just beneath the skin, and they coursed from the base of the penis towards its tip. It therefore seemed possible to cut the flap in such a manner that its attachment or pedicle would be at its proximal end instead of at its distal end, and so preserve its blood supply."

He bent the penis and glans dorsally to the base of the new urethra, which he tunnelled through the glans on to the ventral aspect, in later cases making it long enough to anastomose it to the hypospadiac opening. The base of the pedicle was divided at a subsequent operation at least 3 weeks after the initial operation.

Leadbetter and Leadbetter (1962), and Orandi (1968) described the use of local scrotal skin flaps for the reconstruction of the bulbous urethra for stricture, the former in children and the latter in adults. Blandy and Singh (1975) improved on this, by outlining the scrotal skin island at the apex of the scrotum, with a long "dartos" vascular pedicle, pivoted at its base, making it possible to use the skin island to reconstruct any part of the urethra from the external meatus to the prostatic urethra. The only drawback with the use of scrotal skin was the reported hair balls and calculi which formed in the neourethra.

Recently Jordan and Devine P.C. (1986), have described the use of hairless scrotal island flaps for urethroplasty in stricture.

Orandi (1968) also described longitudinal local ventral penile skin flaps for reconstruction of nearby strictured urethra.

Byars (1955), Broadbent, Woolf and Toksu (1961), Des Prez, Persky and Kiehn (1961), Hodgson (1970), and Asopa (1971), used vascularised preputial island flaps attached to the other layer of prepuce for the neourethra.

Hinderer (1975), Standoli (1977) and Duckett (1980) described transverse preputial flaps with a subcutaneous (subdartos) loose areolar vascular pedicle for reconstruction of the neourethra in hypospadias, Duckett using the inner smooth layer, and Standoli the outer layer.

Most authors agree that a good substitute for the urethra should:

- (i) have epithelium that can withstand the repeated passage of urine.
- (ii) be relatively hairless.
- (iii) have good vascularity for survival in the presence of a poorly vascularised or fibrous bed, or infection.
- (iv) be capable of stretching like the urethra during erections of the penis.
- (v) be capable, in children, of keeping pace with the growth of the rest of the urethra.

Presman and Greenfield (1953) reported an early

successful case, and Devine and Horton (1961), developed the use of free full thickness preputial skin grafts for the reconstruction of the urethra in hypospadias and also in strictures, but even in their expert hands, there was an 85% take. It could not of course, be used in the presence of infection, fistulae, or a poorly vascularised fibrous bed.

The inner layer of the prepuce is completely hairless. The outer surface of the prepuce and most of the distal half of the skin on the shaft of the penis, has very fine lanugo hairs, but the proximal half as one gets near the base, and the scrotum have coarse hair.

Longitudinally aligned penile skin flaps would tend to be hairy proximally, and if fashioned in children, when they appear hairless, would grow hair in adulthood.

In 1953, I attended a lecture on Hypospadias by Denis Browne, at the Royal College of Surgeons of England in London. He mentioned the adaptation of the buried skin strip technique by Johanson, to reconstruct the urethra in stricture.

Since 1953, I have performed Johanson's urethroplasty for strictures, and because of an interest in plastic surgery have tried at the first stage, all sorts of modifications

to bring as much skin as possible to the ventral surface of the penis, by means of rotation and other local flaps, to make for easier urethral reconstruction and skin cover at the second stage.

In 1979, I attended the Congress of the International Society for Plastic and Reconstructive Surgery in Rio de Janeiro, and heard much discussion on axial pattern skin flaps, (McGregor 1973).

I had been using Blandy's scrotal skin flap for urethroplasty in strictures, but was not happy about the hair in the neourethra.

In 1981, I visited the Microsurgery Research Centre at St. Vincent's Hospital, Melbourne, Australia, to learn the basics of microsurgery.

Unaware of the work of Asopa (1971), Hinderer (1975), Standoli (1977) and Duckett (1980), on the use of preputial island skin flaps for urethroplasty in hypospadias, it occurred to me that if the arterial blood supply to the skin of the penis had an axial pattern, an island of transverse distal penile skin or prepuce could be used for urethroplasty in strictures. I mentioned the suggestion at their Journal Club meeting, and was told

that Duckett had then recently described a similar operation for hypospadias, and the idea was sound.

This was the origin of the present anatomical work.

Review of the anatomic literature on the blood supply of the coverings of the penis

Search of the anatomical literature: Gray's Anatomy, Cunningham's Textbook of Anatomy, and Cunningham's Manual of Practical Anatomy, various texts on Applied Surgical Anatomy, and Textbooks on Histology, did not reveal any information on the pattern of the arterial blood supply of the skin or coverings of the penis.

It appears that, because of the great interest in erection of the penis, and potency/impotence, most books on anatomy describe in great detail the distribution of the blood vessels to and from the erectile tissues.

Gray's Anatomy, 36th Edition (1980), describes the superficial external pudendal artery, arising from the medial side of the femoral artery,

"goes medially to the skin of the lower abdomen, the penis and scrotum, or the labium majus anastomosing with branches of the internal pudendal".

The description in the thirty-seventh edition (1989) is almost the same.

Both editions of Gray's Anatomy describe the deep external pudendal artery as supplying the skin of the perineum, scrotum or labium majus.

Cunningham's Textbook of Anatomy (1981), describes the superficial external pudendal artery as supplying the skin of the lower abdomen and pubis, and the deep external pudendal artery as ending on the scrotum or labium majus.

Cunningham's Manual of Practical Anatomy 13th Edition (1966), mentions that the external pudendal, superficial epigastric, and superficial circumflex iliac arteries supply the skin of the external genital organs, the groin, and the lower part of the anterior abdominal wall.

Of the French Anatomists, Sappey (1888), describes in detail the courses of the superior and inferior external pudendal arteries from the femoral artery to the base of the penis, but does not give any details of the disposition of these arteries in the penis.

Testut and Latarjet, in both the 1894 and 1929 editions of their Textbook of Anatomy, describe the mode of termination of the arteries destined for the envelopes of the penis as nothing special, but give a detailed description of the deep arterial network.

In 1887, Manchot in Strasbourg injected and dissected the arteries of the Skin of the whole body, and in his Inaugural Dissertation on "The Cutaneous Arteries of the Body" (1890) has a diagram which shows the distribution of the external pudendal arteries in the penis.

Salmon in a French treatise, published in 1936 on a detailed study of the arteries of the skin and muscles of the body, wrote in the Introduction

"In France, there is no work that describes accurately the origin, distribution, boundaries and anastomoses, in brief the gross and fine anatomy of the skin arteries.

This lack of articles about the arteries of the skin is somewhat surprising, because, for a long time, surgeons have been familiar with the quick necrosis of the skin when it is separated from its feeder vessels." (Translated from the French text.)

He made reference to Manchot's work, and gave details of the distribution of the external pudendal arteries in the penis.

Juskiewenski et.al., in Toulouse, France, did arterial injections and dissections, and also radiological studies

of the arterial blood supply of the penis, and described both the superficial and deep networks in Anatomia Clinica (1982).

Cormack and Lamberty, in their work "The Arterial Anatomy of Skin Flaps" 1986, included a few studies on the arterial supply of the skin of the penis. They quote Conway:

"Detailed knowledge of the vascular anatomy of the arterial circulation of the skin and subcutaneous tissue, is of practical importance to the reconstructive surgeon, who must form and transplant pediculated flaps the viability of which depends on this vascularity."

The present anatomical study of the blood supply of the coverings of the penis was, however, undertaken without any knowledge of the work of the French anatomists, and the work of Manchot.

I met Cormack while he was still working on the book with Lamberty, when he gave a lecture on "Skin Flaps and their Identification by Vascular Injection", at the Royal College of Surgeons of England, London, during a "Macro and Micro Vascular Injection Workshop" in 1983. He saw, and was interested in coloured photographs of my injection studies of the blood supply of the coverings of the penis, and also of the Penile-Preputial Island Flap Urethroplasty for urethral stricture, and he obtained permission to quote my work.

The salient features of the study, which were obvious in the early dissections, were mentioned in my paper "One-stage Penile/Preputial Cutaneous Island Flap Urethroplasty for Urethral Stricture: A Preliminary Report," (1983), and in my coloured motion film "One - stage Penile-Preputial Island Flap Urethroplasty for Stricture", which was first shown without sound at the Congress of the International Urological Society in San Francisco in 1982, and later with sound at the Congress of the International Confederation for Plastic and Reconstructive Surgery in Montreal (1983), and at the Annual Meeting of the American Urological Association Inc., in New Orleans in 1984.

Based on the pattern of the blood supply of the coverings of the penis, and working from the first principles of plastic surgery, and experience with the penile-preputial island flap urethroplasty, I devised in diagrams, a "One-stage clitoral island skin flap vaginoplasty in a female pseudo-hermaphrodite of the adrenogenital syndrome.

This was during a visit of the Operation Smile International Inc. Medical Mission to Monrovia, Liberia in September, 1987, unaware that Dr. Ulrich Hinderer had described a similar operation in 1979.

Based on these diagrams Dr. Lawrence Kurtzmann of Cincinnati, Ohio, and I successfully performed this operation in Monrovia in 1987.

I met Dr. Ulrich Hinderer at the Congress of the International Confederation for Plastic and Reconstructive Surgery in Madrid, Spain, June 28-July 3, 1992. In the mid-1980s, after reading my paper (1983), he had sent me a photocopy of his paper on penis tunnelization flap urethroplasty for hypospadias, which I could not find. I asked him for reprints of his publications on the subject. I received the reprints in August 1992, and he included one on "Reconstruction of the External Genitalia in the Adrenogenital Syndrome by means of a Personal One-Stage Procedure" (1989) and one on "Aesthetic Plastic Correction of Incomplete Testicular Feminization" (1979), which turns out to be similar to the technique I have used.

CHAPTER 2

MATERIALS AND METHODS

Anatomical Dissections

1. The first dissection of the coverings of the penis was done in a mortuary in Melbourne, Australia, in April 1981, in a circumcised male cadaver. A distal transverse or circumferential island of skin with a subcutaneous proximal pedicle was dissected off the fascia penis to the base of the penis, but the vascular pattern was not studied.
2. The second dissection, in a fresh circumcised male cadaver, was performed at the mortuary of the Korle Bu Teaching Hospital, Accra, Ghana, in May 1981, to find out if the pattern of the arterial blood supply to the coverings of the penis was axial or random.

A midline ventral incision was made from the frenum to the penoscrotal junction through skin and subcutaneous tissue down to corpus spongiosum.

A 2cm wide island of skin of the complete circumference of the penis, just behind the coronal sulcus, was demarcated by skin deep incisions, and the skin proximal to it dissected off the subcutaneous tissue.

After deepening the distal skin incision behind the coronal sulcus down to the fascia penis, the skin island and subcutaneous tissues as pedicle, were together dissected off the fascia penis to the base of the penis, and the vascular pattern observed.

This was the feasibility study.

3. Gross dissections were carried out on the femoral triangles and penis in fresh cadavers, to trace the superficial (superior) and deep (inferior) external pudendal arteries from their origins from the femorals, to their distribution in the penis, and to study the venous drainage of the coverings of the penis.

- (i) in male adults
- (ii) in male children
- (iii) in still born male babies

In the still born babies and some of the male children, 2.5x operating loupes were worn for the dissection.

4. Gross dissections were carried out as in (3) above in embalmed cadavers, after injection of the femoral arterial system with maroon (red) coloured latex or

microfil silicone rubber.

4.1 Injection Techniques

4.1.1 Canulation

Initially the external pudendal arteries were directly canulated, using locally made plastic canulae, but later the femoral or external iliac arteries were canulated on one side only - either the left or right.

In early cases the canulated femoral artery was also ligated more distally just proximal to the profunda femoris artery, but this procedure was discontinued, because it did not seem to improve the results of the injection.

Only one side was canulated because the injected latex or microfil usually filled up the arteries on the contra-lateral side.

4.1.2 Coloured latex injection.

4.1.2.1 The local arterial tree was washed out by the injection of 10-20 ml. 10% ammonia solution through the canula, to make it

alkaline, as acidity causes premature setting of the latex.

4.1.2.2 In babies 10ml., and in adults 20ml., of coloured latex were then injected through the canula.

4.1.3 Coloured microfil silicone rubber injection.

Microfil is supplied in kits containing rubber compound, diluent, and curing agent. The compound is blended with diluent in the proportion 4ml. compound to 5ml. diluent. To this mixture, just under 0.5ml catalyst is added just prior to the injection. Working time is 15 minutes from the time of adding the catalyst.

10ml. of mixture is used for injection in babies, and 20ml. for injection in adults.

(Microfil is the Trademark of Canton Bio-medical Products of Boulder, Colorado, U.S.A. for silicone rubber.)

4.1.4 We have not had to make separate

injections of the venous system, as the blue deoxygenated haemoglobin in the veins is clearly visible even in the small venae comitantes, and in the uninjected cadavers often helps to locate the arteries.

4.2 Dissection

Dissections were performed at least 24 hours after the injection.

4.3 Gross dissections were performed as in (4.2) above in fresh still born babies, after arterial injection of coloured microfil silicone rubber as in (4.1.3), or latex injections as in (4.1.2) above.

5. Cross-sections of the prepuce, stained with haematoxylin and eosin were examined microscopically.

6. Cross-sections of the penile shaft stained

(a) with haematoxylin and eosin
and

(b) Masson's stain

were examined both macroscopically and microscopically.

7. Superficial venous drainage of penis

Observations were made of the superficial venous drainage of the penis in live male subjects.

8. Penile-preputial island skin flap urethroplasty (PIFU)

Observations were made of the vascular pattern of the skin and subcutaneous tissues during penile/preputial island flap urethroplasties in over 100 male adults and children, for urethral strictures and hypospadias.

9. Clitoral island skin flap vulvo-vaginoplasty

In 2 female pseudo-hermaphrodites, due to the adrenogenital syndrome, the coverings of the hypertrophied clitoris were used as an island flap to reconstruct the distal vagina and introitus in a 13 year old, and to reconstruct the labia minora in a 9 year old.

CHAPTER 3

RESULTS - OBSERVATIONS

Feasibility Study

1. The first dissection done in Melbourne, Australia showed that it was possible to fashion a transverse distal penile-preputial island of skin on a subcutaneous pedicle pivoted at the base of the penis, but no close observation was made of the vascular pattern of the pedicle.

2. In the second dissection done in Accra, Ghana, a transverse distal penile skin island of the whole circumference of the penis was raised on a proximal subcutaneous pedicle pivoted at the base of the penis.

Very definite axial arteries and venae comitantes were seen running longitudinally down the pedicle, Fig.1:

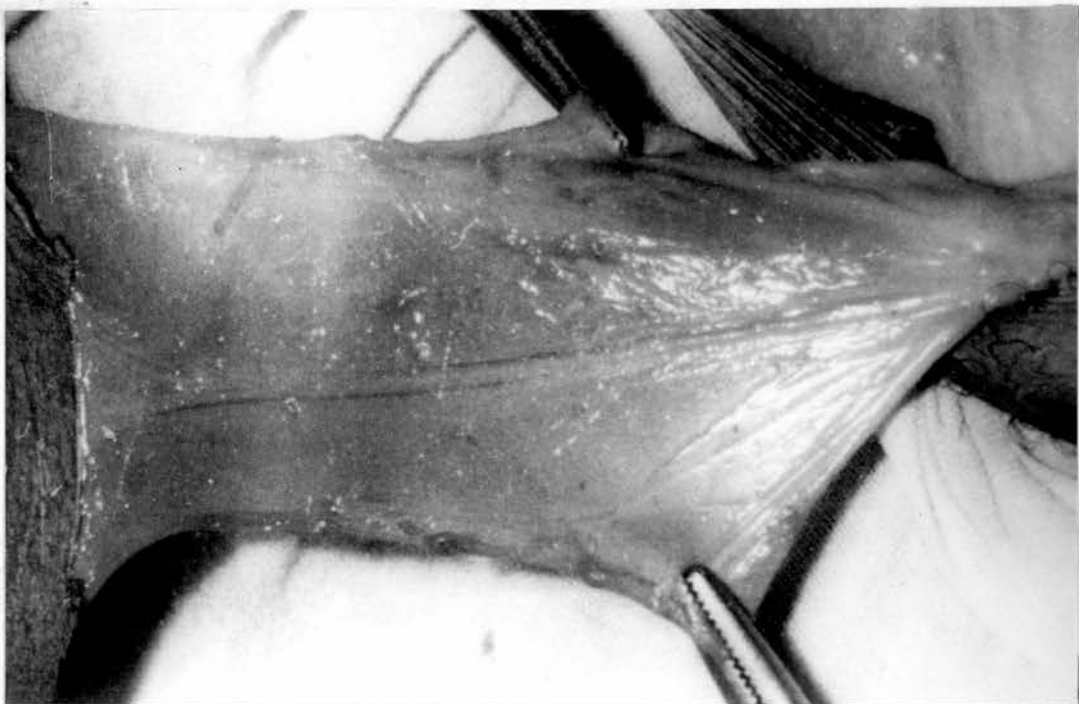


Fig. 1 Axial artery with venae comitantes

The length of the skin island obtained from the circumference of the distal penis was 13-14cm Fig.2:

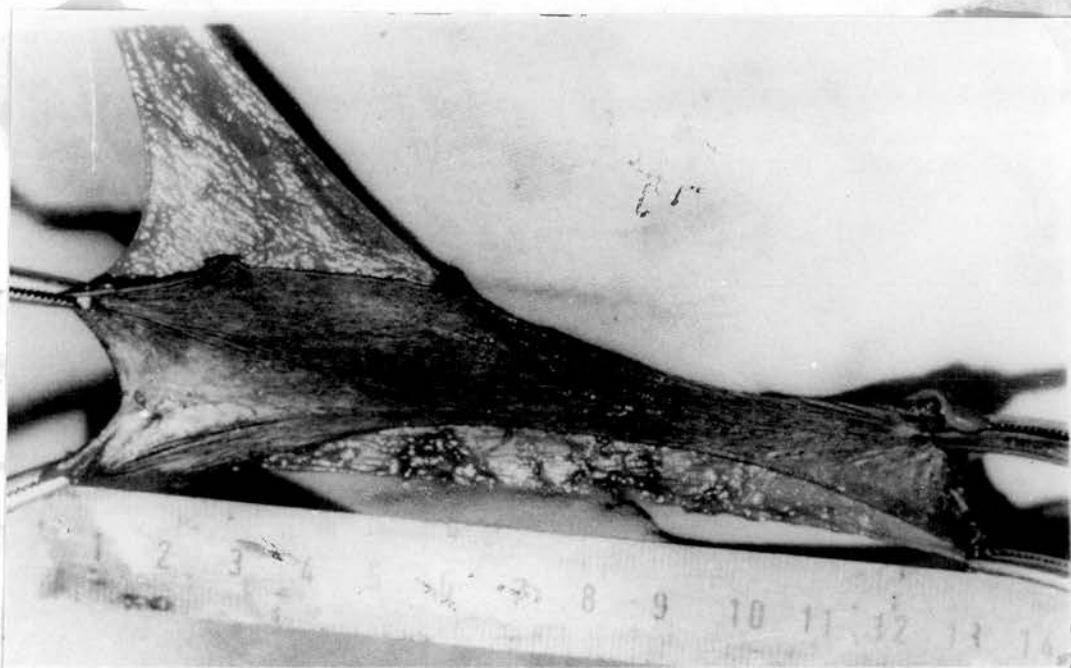


Fig. 2 Skin island from circumference of distal penis

and the length of the vascular pedicle was also 13-14cm. long. Fig.3:



Fig. 3 The vascular pedicle

This feasibility dissection proved definitely that;

- (a) there were axial arterial branches running in the pedicle, with venae comitantes, which would make viable a transverse distal island of penile/preputial skin for urethroplasty;

- (b) the vascular pedicle was long enough for the distal skin island to be used to reconstruct the urethra anywhere from the external urinary meatus to the membranous urethra.
 - (c) it is possible to get skin islands to reconstruct defects in the urethra up to about 14cm in length.
3. The dissections of the femoral triangles and penis to show the arterial blood supply to, and venous drainage of the coverings of the penis, show that there are considerable variations in the pattern of distribution.

CHAPTER 4

ARTERIAL BLOOD SUPPLY OF THE COVERINGS OF THE PENIS

The arterial blood supply of the coverings of the penis is derived from the superficial (superior) and deep (inferior) external pudendal branches of the first part of the femoral arteries.

Superficial (Superior) External Pudendal Artery

The superficial external pudendal artery arises from the antero-medial aspect of **the first** part of the femoral artery, about 2cm **distal to the** inguinal ligament in the adult. It passes medially **anterior** to the femoral vein, usually above the sapheno-femoral junction, or anterior to the saphenous vein, pierces the antero-medial part of the femoral sheath, to run a horizontal course medially in the superficial fascia. Near the scrotum it divides into two branches, a superior, which passes supero-medially on to the abdomen, towards the umbilicus, and an inferior, which continues a medial or infero-medial course, crosses superficial to the spermatic cord and may end in one of several ways, in the subcutaneous loose areolar tissue of the penis:

- (a) after giving off short pubic skin branches, the artery from each side may end as an axial branch running in the subcutaneous areolar

tissue, on the dorso-lateral aspect of the penis from the base towards the prepuce.

- (b) the artery from one side may cross over the dorsum of the penis to the other side, supplying the ipsi-lateral dorso-lateral, most of the dorsum and most of the contra-lateral sides. Fig.4:



Fig 4. Dominant superficial external pudendal artery

- (c) the inferior branches from both sides anastomose across the front of the pubis, and from the network formed a dorsal or two dorso-lateral axial branches pass distally into the penis.

In one cadaver, the dorso-lateral branch from the pre-pubic anastomosis joined a dorso-lateral branch of the deep external pudendal artery. Fig.5:

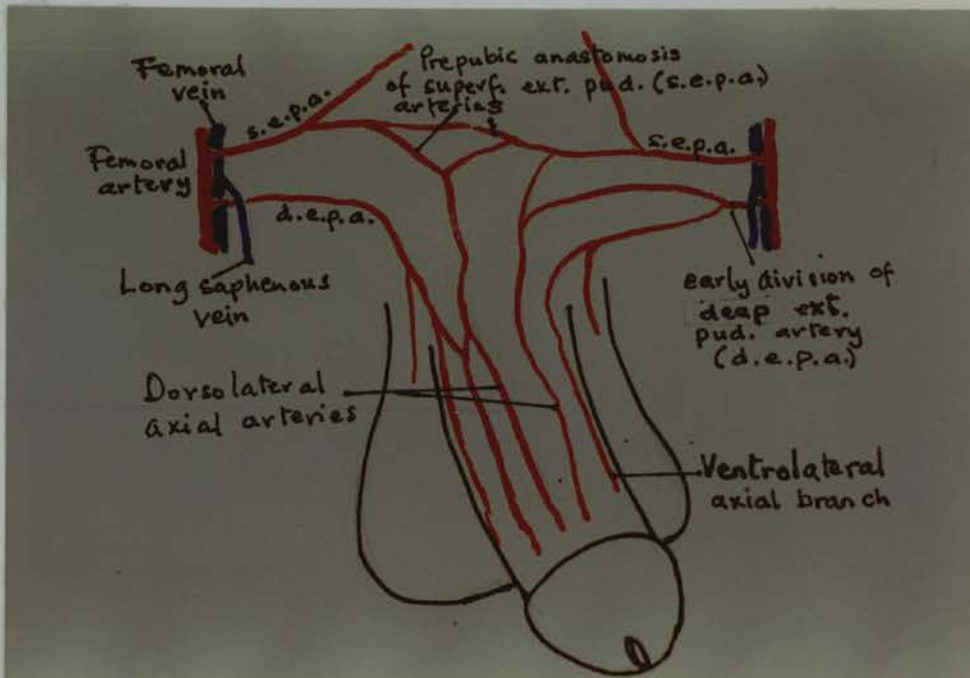


Fig. 5 Anastomoses between superficial and deep external pudendal arteries

Deep (Inferior) External Pudendal Artery

The deep (inferior) external pudendal artery arises from the antero-medial side of the femoral, at a level just distal to the sapheno-femoral vein junction, about 2-3cm. distal to the origin of the superficial external pudendal artery. In most cadavers it passes medially posterior to the long saphenous vein, and anterior to the femoral vein. It runs horizontally sometimes in the deep fascia across pectineus and adductor longus muscles, occasionally passing deep to adductor longus muscle, to emerge at its medial border, where it may pass anterior or posterior to the spermatic cord; sometimes from its origin, it soon pierces the deep fascia to run in the superficial fascia.

In many cases it divides at the base of the penis into a superior axial branch, which runs towards the glans and prepuce, in the loose areolar tissue on the dorso-lateral aspect, and an inferior branch, which after giving off anterior scrotal branch or branches, runs axially on the ventro-lateral aspect of the penis in the loose areolar tissue. Fig.6:

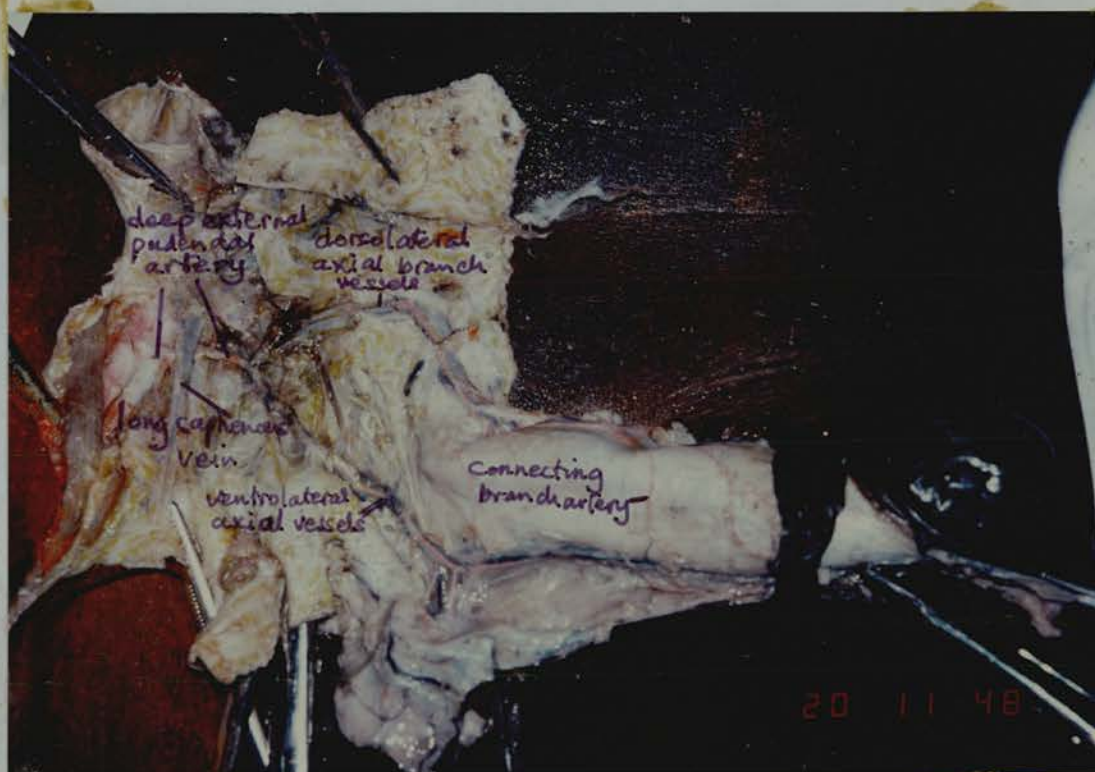


Fig. 6 Dominant deep external pudendal artery

Occasionally the division into superior and inferior branches is early, soon after emerging from behind the long saphenous vein, Fig. 5.

Sometimes, after giving off the anterior scrotal branches the main artery becomes the ventro-lateral axial branch of its side.

In quite cadavers there is considerable anastomosis between branches of the superficial and deep external

pudendal arteries either near their origins, or near the base of the penis as in Fig.5.

In one cadaver the femoral artery divided high up into a profunda femoris and a continuation femoral of nearly equal sizes, after giving off the superficial external pudendal artery, and the deep external pudendal artery originated from the continuation femoral. Fig.7.

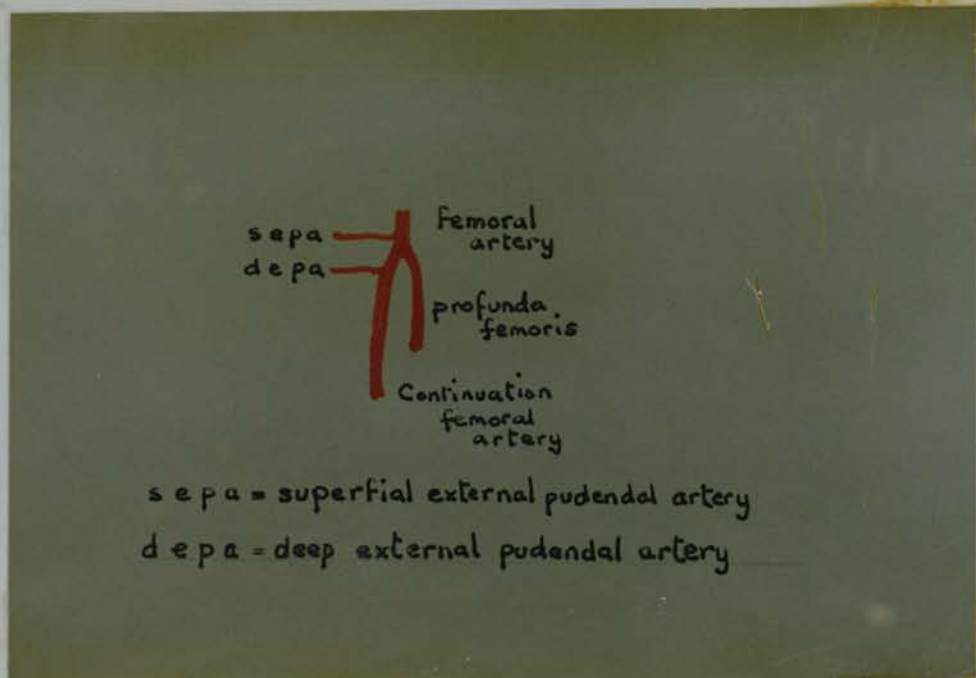


Fig. 7 High division of femoral artery

Occasionally the superficial and deep external pudendal arteries arise from a common trunk at the normal level of

the deep artery, Fig. 8:



Fig. 8 Superficial and deep external
pudendal arteries arising from common
trunk

Near its termination it passes anterior to the spermatic cord, but occasionally it may pass posterior to the cord.

Terminal Axial Branches of the Superficial and Deep
External Pudendal Arteries.

The Superficial and deep external pudendal arteries end

up basically as four axial branches running in the loose subcutaneous areolar tissue, along the shaft of the penis, to the glans and prepuce i.e. right and left dorsolateral and ventrolateral axial branches.

In the majority of bodies, the deep external pudendal artery divides into the terminal dorsolateral and ventrolateral axial branches, either equally from the two sides, or predominantly from one side. In many bodies however, the superficial ~~external~~ pudendal artery either becomes the dorsolateral axial branch, sends dorsolateral or dorsal axial branches from the prepubic anastomosis formed by the arteries of the two sides, or contributes significantly to the arterial supply of the coverings of the penis through its anastomoses with the deep external pudendal artery, before its termination as axial branches. Occasionally the superficial external pudendal artery of one or both sides may predominantly supply most of the dorsolateral and ventrolateral axial branches.

The terminal axial arterial branches often subdivide and reanastomose.

There are cross connections between the axial arterial branches on each side, Fig.7, and across the midline between the two sides, resulting in the formation of a superficial or what might more accurately be termed

intermediate arterial plexus in the loose areolar tissue. From this arterial plexus, fine scattered branches pass superficially to the subdermal (subdartos) arterial plexus, which nourishes the skin-dartos unit, and also to the deep arterial plexus formed by the dorsal and circumflex arteries. These fine branches can be seen when dissecting the skin off the subcutaneous tissue, or separating the subcutaneous tissue from the fascia penis in the fresh cadaver. This is appreciated in patients during the penile-preputial island flap urethroplasty, by the initial punctate **oozing of blood** on the surfaces of the skin-dartos unit, **the vascular pedicle**, and the fascia penis, even though the separation of the layers are relatively bloodless. Sometimes the branches to both skin-dartos unit, and through fascia penis are large enough to require clamping, division, and ligation or cauterization before separation of the layers can be completed.

The Subdermal (Subdartos) Arterial Plexus

From mainly near the base of the penis, usually before entering the shaft, the dorsolateral and ventrolateral axial arteries give off branches which run distally in the subdermal or subdartos layer, branching and reanastomosing to form a subdermal (subdartos) plexus, which nourishes the skin-dartos unit Fig.9.



Fig. 9 Branches from axial penile arteries to
subdermal arterial plexus

As mentioned above, this plexus is joined along the shaft of the penis by fine and tenuous, but occasionally large branches from the arterial plexus in the loose areolar tissue.

Connections between the arterial plexus in the loose areolar tissue, and the deep arterial plexus.

Behind the coronal sulcus, at the base of the prepuce,

the axial branch arteries give off larger perforators, which pierce the fascia penis to join the deep plexus formed by the dorsal and circumflex arteries and then send smaller branches to end in the prepuce. From the terminal preputial arteries, can be seen fine branches passing superficially to the outer preputial skin, or deeply to the inner preputial skin. They are longish and tenuous and mostly run an oblique course and are given off even before the preputial arteries enter the base of the prepuce. The perforators are the main connection between the intermediate and deep arterial plexuses. In addition, along the shaft of the penis, there are fine but occasionally large connections between the two plexuses.

The presence of the perforators can be seen from the positions of the arterial bleeding points during the operation of distal penile-preputial island flap urethroplasty, when dissecting the subcutaneous tissue off the fascia penis at the distal end of the penis behind the corona.

VENOUS DRAINAGE OF THE COVERINGS OF THE PENIS

The **superficial** system of veins draining the skin-dartos unit and subcutaneous tissues of the penis can be grossly classified :

1. Sub-dermal (subdartos) plexus of veins. They can be seen both in the cadaver, and at penile-preputial island flap urethroplasty, when the skin-dartos unit is dissected off the loose areolar subcutaneous vascular tissue. They hug the dartos layer and together with the subdermal (subdartos) plexus of arterioles nourish the skin and dartos. More proximally, the tributaries join up to form more distinctive veins which become tributaries of the large independent veins, or the venae comitantes of the axial arteries, or trunk veins which join them at or near the base of the penis to form the external pudendal vein. Fig.9 and Fig.10.





Fig. 10 Subdermal veins

2. Large independent (communicating) veins.

Most anatomy books describe only the superficial dorsal median vein or veins. Fig.11.



Fig. 11 Superficial dorsal median vein

In fact, in many of the penises we have observed, both in cadavers and in live patients, there are also large visible lateral veins, which may sometimes be ventro-lateral or dorso-lateral. Fig.12 and Fig.13:



Fig. 12 Superficial lateral vein



Fig. 13 Superficial ventrolateral vein

These communicating independent veins usually arise from the retrobalanic plexus of veins, and emerge just **behind** the coronal sulcus, where they are joined by the preputial veins.

Through the retro-balanic **plexus** they are connected to the deep dorsal median vein or veins which arise from the same source. This is one of the main connections between the superficial and deep venous systems of the penis, Fig. 14:

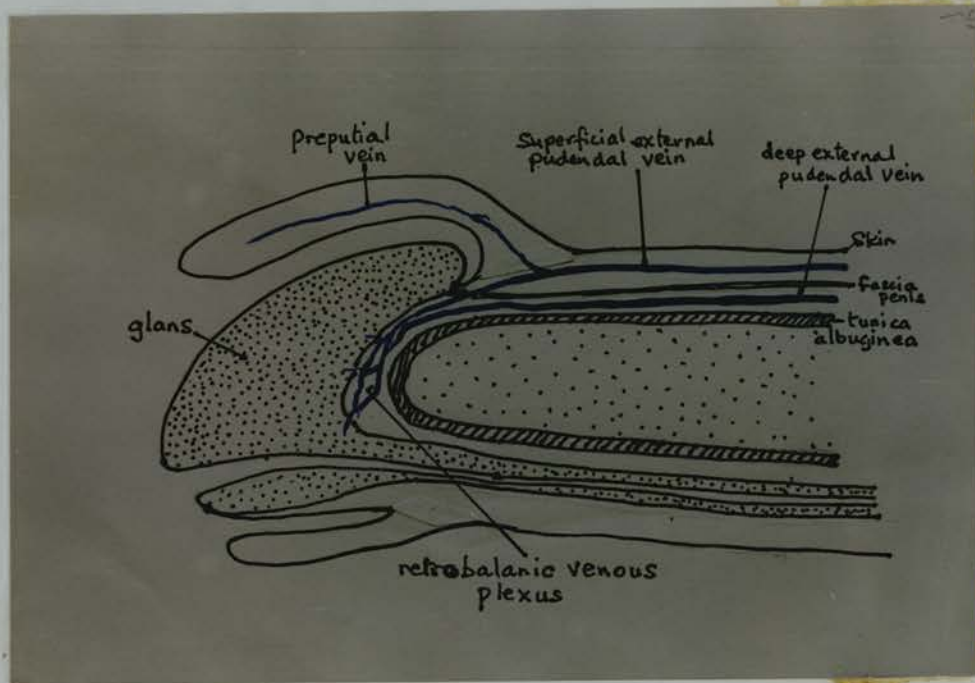


Fig. 14 Origin of superficial and deep dorsal median veins (Schematic)

Sometimes the large superficial independent veins arise directly from the circumflex veins, tributaries of the deep dorsal median vein, running between the fascia penis and the tunica albuginea of the corpora cavernosa. Fig.15.



Fig 15 Large tributary from circumflex vein to superficial dorsolateral vein

Occasionally, they arise directly from the deep dorsal median vein or veins. In both cases they pierce the fascia penis to enter the subcutaneous tissue. Fig.16, and Fig. 17:



Fig. 16 Superficial dorsal median arising from deep dorsal median vein

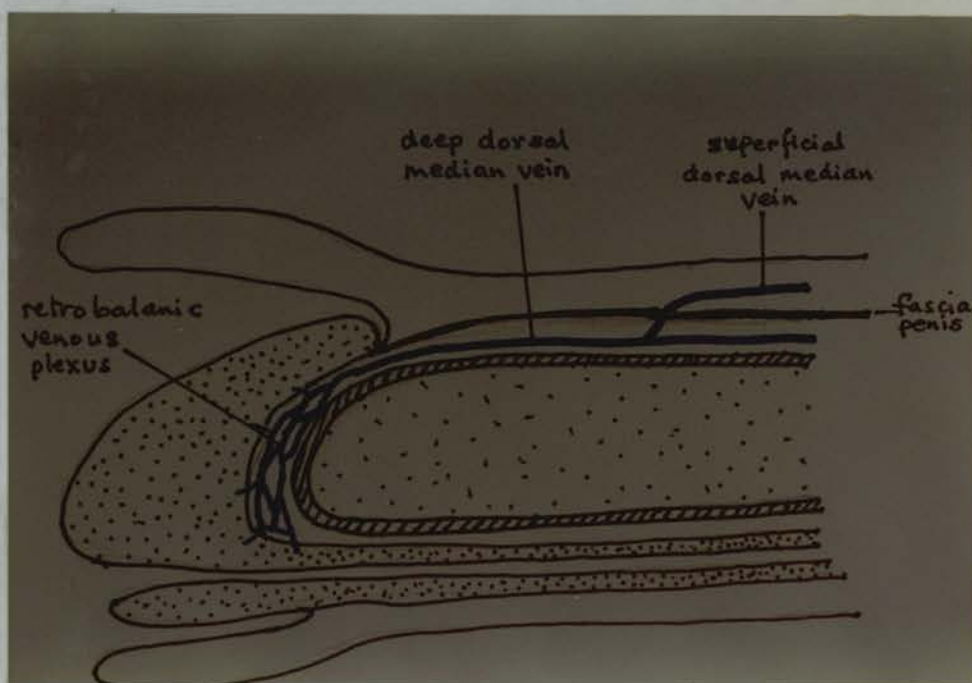


Fig. 17

When they arise from the circumflex or deep dorsal median veins the connections have to be clamped, divided, and ligated before the loose areolar vascular pedicle can be separated from the fascia penis, in the operation of penile-preputial island flap urethroplasty, or in cadaver dissection.

This is another connection between the superficial and deep venous systems.

If there are more than one dorsal median vein, they may unite anywhere along the shaft of the penis into a single trunk.

The single trunk vein may, at the root of the penis, pass to one or other side, but more frequently to the left, as found by most observers. The trunk may, however, divide into right and left branches, which join lateral penile veins, the venae comitantes of the axial penile arteries, the veins from the subdermal vascular plexus, and the anterior scrotal veins to form the superficial external pudendal vein, which usually ends in the long saphenous vein just before it terminates in the femoral. Fig. 18:



Fig. 18 Superficial dorsal median vein
dividing into right and left branches

Occasionally, if there are two superficial dorsal median veins, which do **not** unite, they may pass to their respective sides at the base of the penis and end in the superficial external pudendal vein of those sides.

At the base of the penis in the prepubic area, there are often connections between these superficial penile veins, and the inferior epigastric veins, but

we have not come across the connections with the obturator and deep dorsal median veins in this region as described by other authors.

3. Venae Comitantes of the penile axial branches of the external pudendal arteries.

Venae comitantes of the **axial** branch arteries of the penis, are easily visible **in the** arterially injected cadavers, and in the **uninjected** cadavers especially, they often help in the location of the arteries, Fig.19.



Fig. 19 Venae comitantes of axial arteries

At the base of the penis, they join the large independent, and other veins to form the superficial external pudendal vein.

5. Random veins

Fine random veins without set pattern often join up to form small recognizable veins which join the venae comitantes or the large independent veins.

Like the arterial system there is generally only fine connections along the shaft of the penis, between the subdermal (subdartos) plexus of veins and the large independent veins and venae comitantes, or between these and the deep dorsal and circumflex veins, but as previously mentioned, may occasionally be large enough to require clamping, division and ligation either at operation or in the cadaver before the layers can be separated. The main connections are at the base of the prepuce, behind the coronal sulcus, or at the base of the penis.

Noticeably the large independent veins seem to be riding on the surface of the loose areolar subcutaneous tissue, whereas the axial branch arteries and their venae comitantes run in the subcutaneous tissue. In embalmed cadavers, the subcutaneous tissue can almost be peeled

off in layers, with the independent veins in the superficial layer, and the arteries in the deeper layers.

of a fan-shaped

with the large

ring

CHAPTER 6

LAYERS OF THE COVERINGS OF THE PENIS

Macroscopically the coverings of the penis are in three layers.

1. The skin-dartos unit.

The skin-dartos unit forms the outermost layer, consisting of the skin with the deepest layers of the dermis intimately blending with the dartos muscle layer. Just deep to the dartos muscle layer is the subdermal (subdartos) plexus of blood vessels which nourishes the skin-dartos unit.

2. Loose Cellular areolar subcutaneous tissue.

The Loose areolar subcutaneous tissue lies deep to the dartos muscle with the large independent superficial veins running in its superficialmost layers, and the axial branch arteries and their venae comitantes in its middle.

3. Fascia penis (Buck's fascia)

This is a thin sheet of elastic tissue deep to the

loose areolar subcutaneous tissue and closely applied on its deep aspect to the corpora cavernosa and corpus spongiosum, which it binds into a single erectile unit. Between the fascia penis and the tunica albuginea of the corpora cavernosa lie the deep dorsal vein or veins, the dorsal arteries and nerves, and the circumflex vessels. Fig.20:

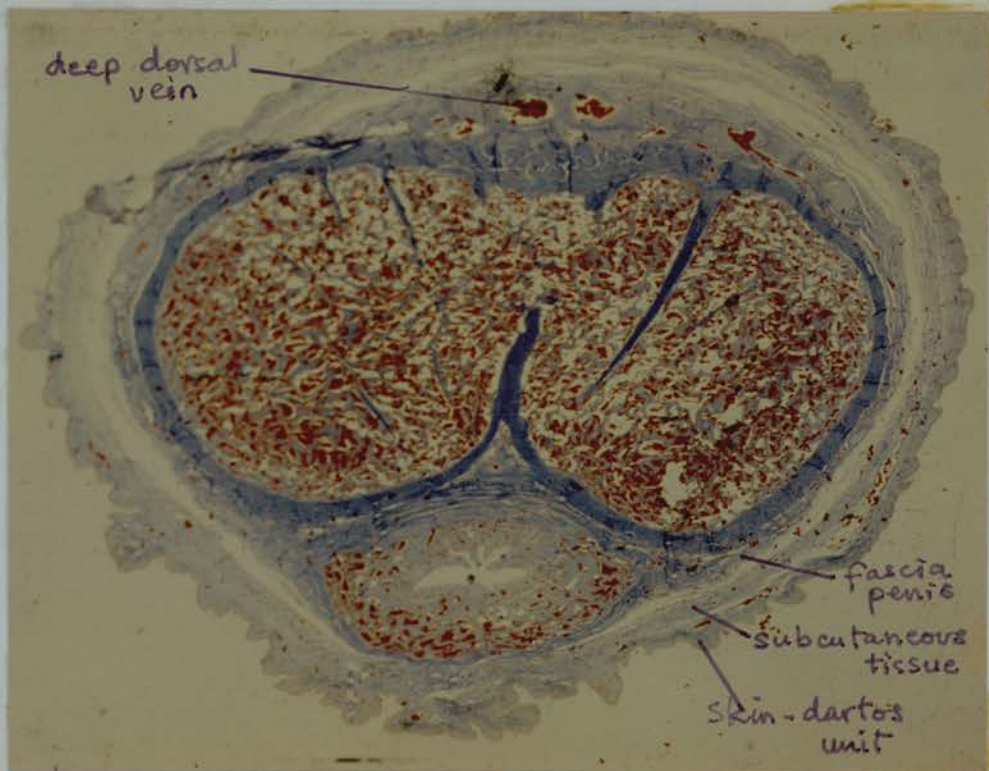


Fig. 20 Cross-section of penis showing the layers

There is a definite plane of cleavage between the

skin-dartos unit and the loose areolar subcutaneous tissue, which makes it possible easily to separate the two layers by either blunt or sharp dissection. Because the branches connecting the blood vessels in the loose subcutaneous unit to the subdermal (subdartos) plexus of blood vessels are fine and sparsely scattered over the shaft of the penis, the separation of the two layers is almost bloodless, but as previously mentioned these connections are sometimes large enough to require clamping, division and ligation.

There is also a definite plane of cleavage between the loose areolar subcutaneous tissue and the fascia penis, which makes it possible to separate them almost bloodlessly by blunt or sharp dissection. Again, the odd large connection between the blood vessels in the subcutaneous tissue, and the deep group of dorsal and circumflex blood vessels has to be clamped, divided, and ligated to be able to make the separation. An island of transverse preputial or distal penile skin can therefore be raised on a pedicle of the vascular loose areolar subcutaneous tissue, for reconstruction of the urethra, and when the vascular pedicle is pivoted at the base of the penis, it is found to be long enough to enable the skin island to reach any part of the urethra from the external meatus to the prostatic urethra. Fig.21:

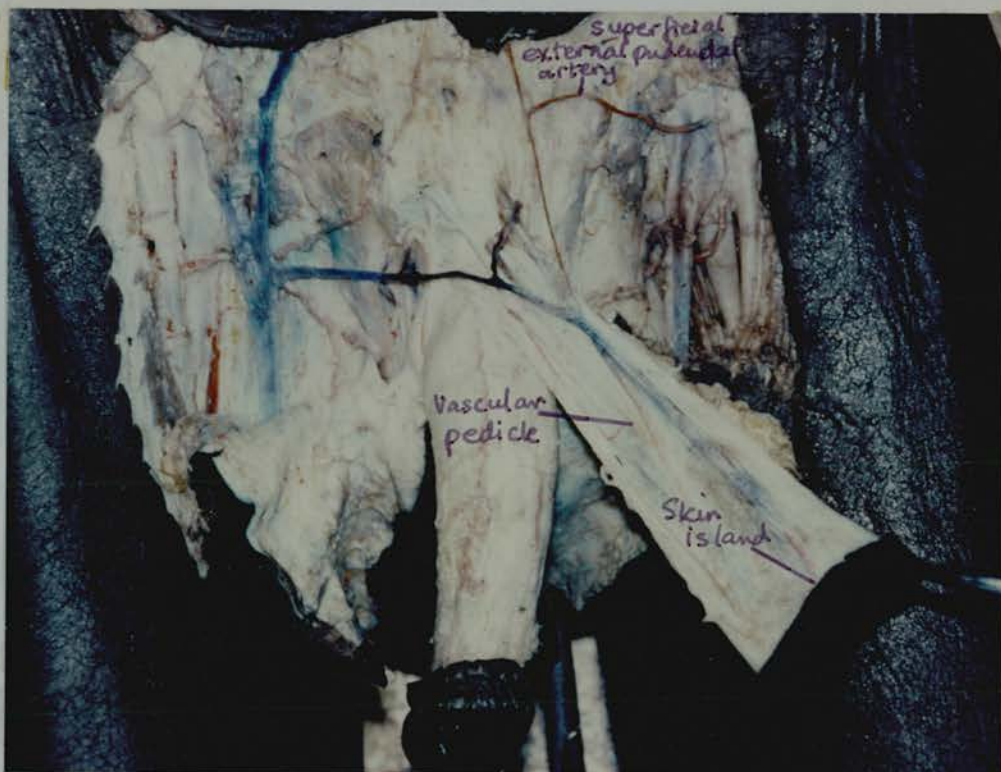


Fig. 21 Skin island on vascular pedicle

In raising flaps of penile or preputial skin, dissection should always be in the two planes of separation or cleavage just described, in order to preserve the blood vessels, and to achieve a relatively bloodless dissection.

CHAPTER 7

TRANSVERSE DISTAL PENILE-PREPUTIAL ISLAND SKIN FLAP URETHROPLASTY FOR STRICTURE

The distal transverse penile-preputial island skin flap can be used to reconstruct the urethra in urethral stricture as a patch or as a tube.

Technique

(a) Patch Urethroplasty

The affected part of the urethra is exposed through a skin incision or incisions.

The urethra distal to the distalmost stricture is opened by incising over a metal sound and the opening extended distally 1-2cm into normal urethra.

The incision in the urethra is extended through all the strictures, opening them up and 1-2cm into normal urethra proximally. In the bulbo-membranous area, it may be necessary to pass a sound antegrade through a suprapubic cystostomy to identify the proximal urethra.

The length of the defect to be reconstructed is measured. Most of the time, in the absence of a metal rule or calipers, a piece of black silk clipped with mosquito artery forceps at the appropriate points is used for the measurement.

The shape of the ~~skin~~ island will depend on the defect. In single ~~localised~~ strictures, it would be lozenge ~~shaped~~ or oval; in multiple strictures, more complex.

The length of the skin island to be used is marked just behind the coronal sulcus, starting from the frenulum and passing circumferentially round the distal penis on one side. It is important to put the skin on the stretch with skin hooks or Allis' forceps when marking, as otherwise the island of skin would ultimately be found to be too big. In the absence of a marking pen the back of the tip of a scalpel can be used.

In the circumcised patient, the distal margin of the skin island is about 1cm behind the coronal sulcus at the distal margin of the penile skin.

In the uncircumcised, the prepuce is usually pulled back over the distal shaft behind the glans before marking, so that the island is made up mostly of inner preputial skin.

An incision is made transversely along the distal margin of the skin island, and deepened down to the fascia penis, and from the frenal end in the midline ventrally to the peno-scrotal junction and deepened down to the shiny bluish corpus spongiosum.

Stay sutures are inserted at the edges of the flap at the peno-scrotal and frenal junctions and sometimes in between, and then at about 2-3cm. apart along the distal margin.

The flap of skin-dartos unit, together with the loose areolar subcutaneous tissue containing the blood vessels is dissected off the fascia penis. It is usually found that as the flap is dissected and elevated, the length is far greater than marked out, because of the elasticity of the skin-dartos unit. Fig.22

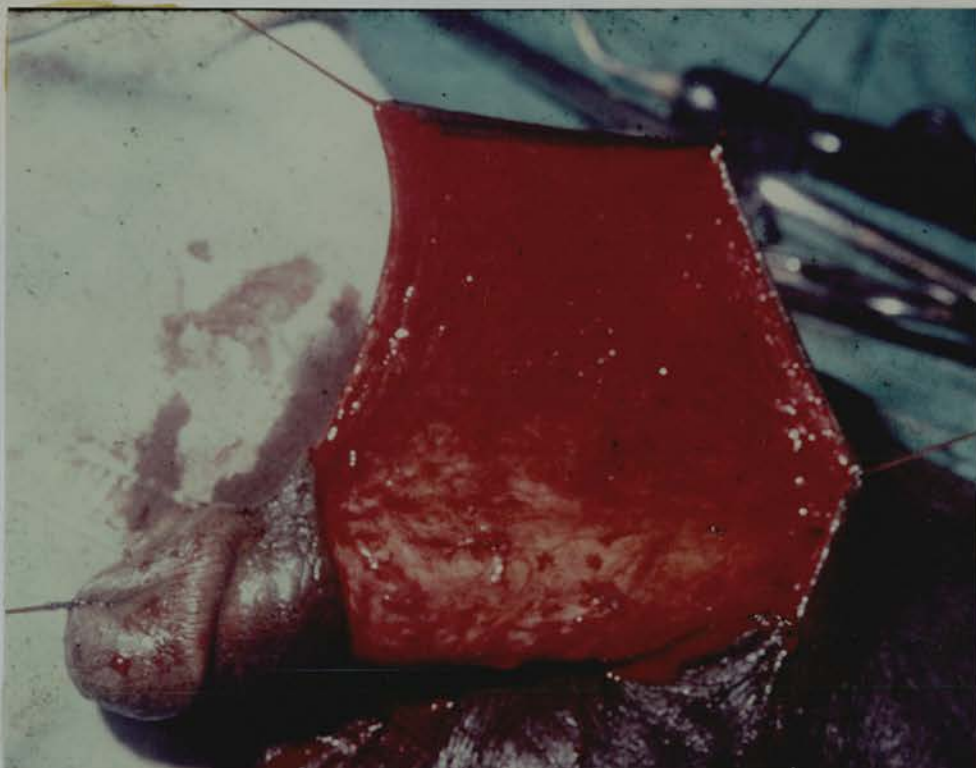


Fig. 22 Flap of skin and vascular subcutaneous tissue

Next a skin deep incision is made at the proximal edge of the skin island, and the proximal skin-dartos unit dissected off the loose areolar subcutaneous vascular pedicle.

Fig.23 and Fig. 24



Fig. 23 Skin deep incision at proximal edge of skin island

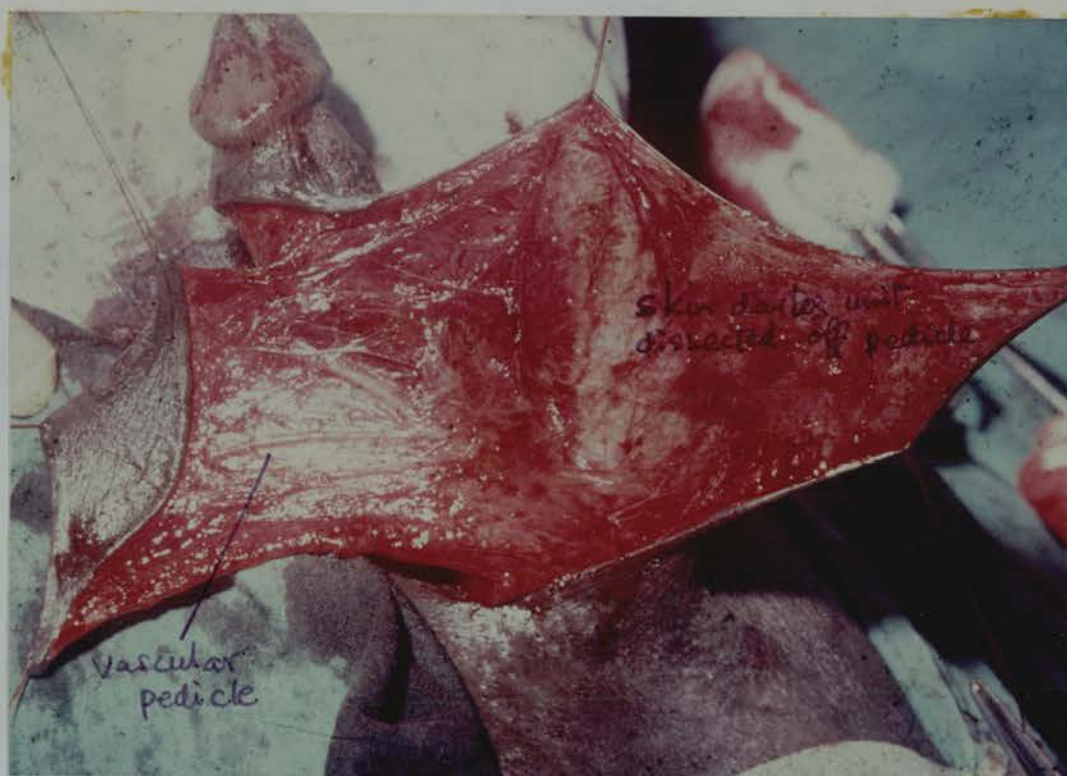


Fig. 24 Proximal skin-dartos unit dissected off vascular pedicle

If the skin of only part of the circumference is being used, a longitudinal incision separates the island and its vascular pedicle from the proximal elevated and the unelevated covering of the penis, freeing the vascular pedicle, and making it mobile. Fig. 25

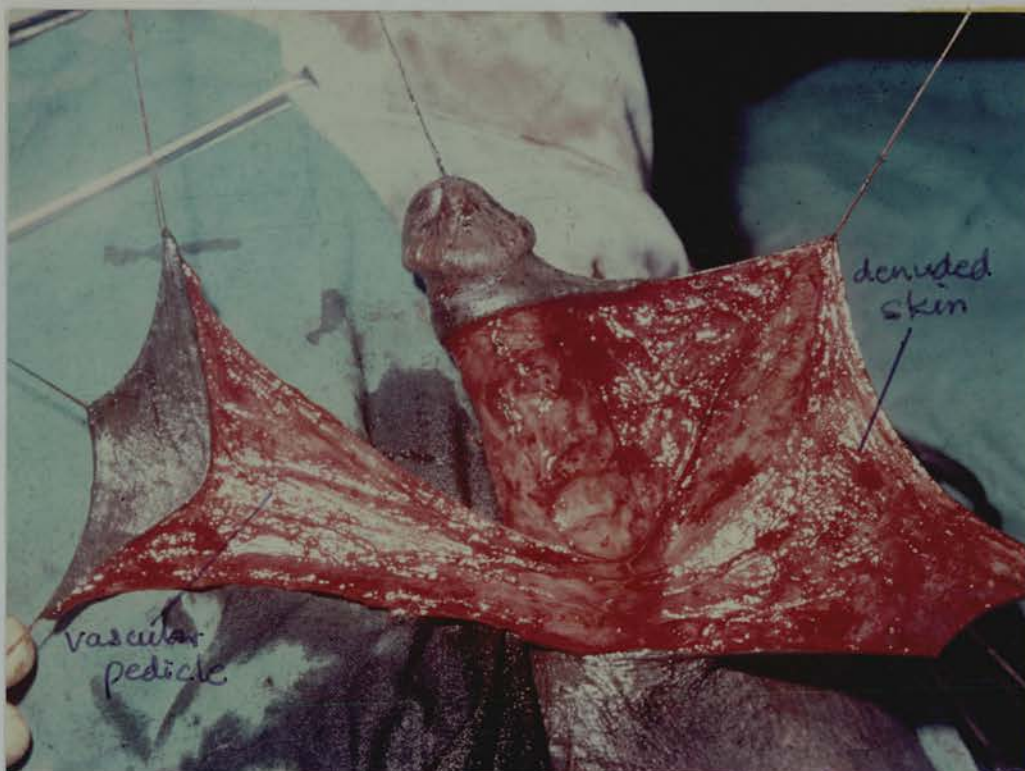


Fig. 25 Vascular pedicle freed and mobile

In long multiple strictures, if the skin of the whole circumference of the penis is being used, the proximal skin-dartos unit is dissected off the whole circumference of the subcutaneous vascular pedicle. The longest defect for which a whole circumference of penile skin was used for a patch flap reconstruction was 17cm. and that was not from an excessively large penis.

The length of pedicle mobilised depends on the

site and length of the stricture(s) but should be long and loose enough to avoid tension on the skin-urethral anastomosis.

For bulbo-membranous urethral strictures, which are exposed through a perineal incision, the skin island and vascular pedicle are passed through a tunnel under the scrotum into the perineum, Fig.26.



Fig. 26 Skin island and pedicle passed into perineum

Interrupted 4/0 or 5/0 polyglactin sutures tied outside the lumen, are used to approximate the edges of the skin island to the edges of the urethral defect over a 16Fr. indwelling Foley catheter, making sure to secure accurate skin-mucosal apposition in one layer.

In the presence of ~~infection~~ in the reconstruction area, ~~such~~ as after excision of concomitant abscesses or urethro-cutaneous fistulae, the wound is drained, preferably with a suction tube before closure. Clean wounds may or may not be drained, depending on the amount of bleeding present.

The raw shaft ~~of the penis~~ from which the flap has been dissected, is re-covered with the proximal skin-dartos unit, which was dissected off the vascular pedicle (the denuded skin flap). Sometimes the frenal corner of this denuded skin turns purplish or blue, in which case, it should be excised before the skin is sutured back over the penis.

(b) Tube Urethroplasty

Where a segment of strictured urethra is

impassable and badly scarred, with little or no mucosa left, and where excision and end to end anastomosis of the urethra is impracticable, excision and reconstruction of the defect with a tubed penile-preputial island flap is appropriate.

Different parts of **the strictured** urethra are mobilised through **standard** exposures.

The normal urethra distal and proximal together with the stricture(s) are mobilised in continuity, and after defining the distal and proximal limits of the stricture with sounds, section is made through normal urethra just distally and proximally. **The distal and proximal urethral stumps are spatulated.**

In bulbo-membranous urethral strictures, mobilisation of the **stricture(s)** and adjacent normal urethra in continuity, avoids cutting through the very vascular spongy tissue of the bulb, with its attendant bleeding. Opening of localised strictures, and in bulbo-membranous strictures, spatulation of the distal urethral stump after excision of the stricture is done on the less vascular dorsal or dorsolateral

aspect, Fig.27.

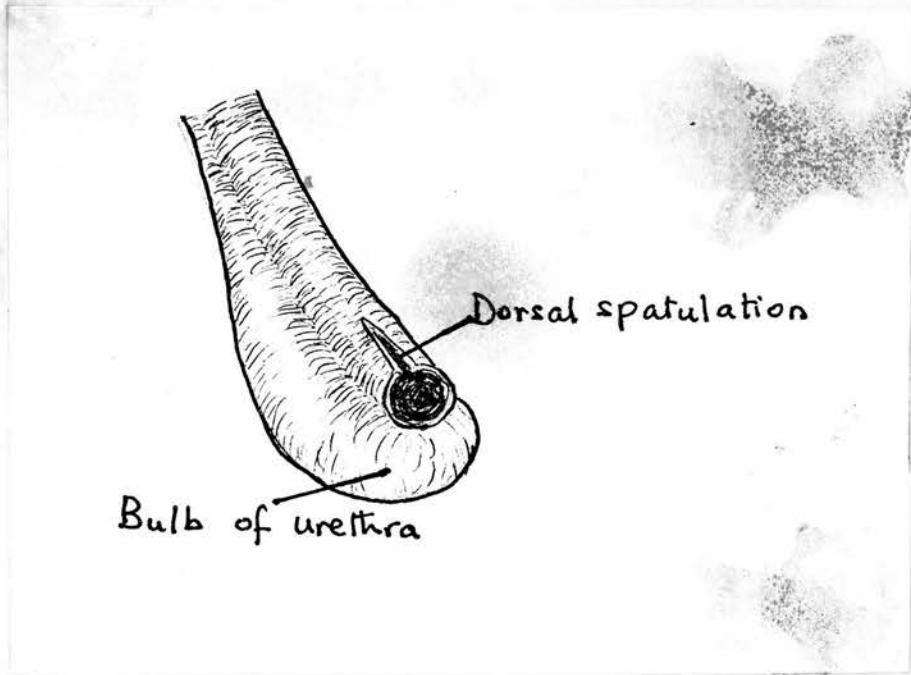


Fig. 27 Dorsal spatulation of proximal bulbous urethral stump

The skin island is hexagonal in shape, so that when tubed, the ends are oblique, with the long side fitting into the spatulations. The width of the skin island is 2.5cm in adults, and about 1.5cm in children. Fig.28 and Fig.29.

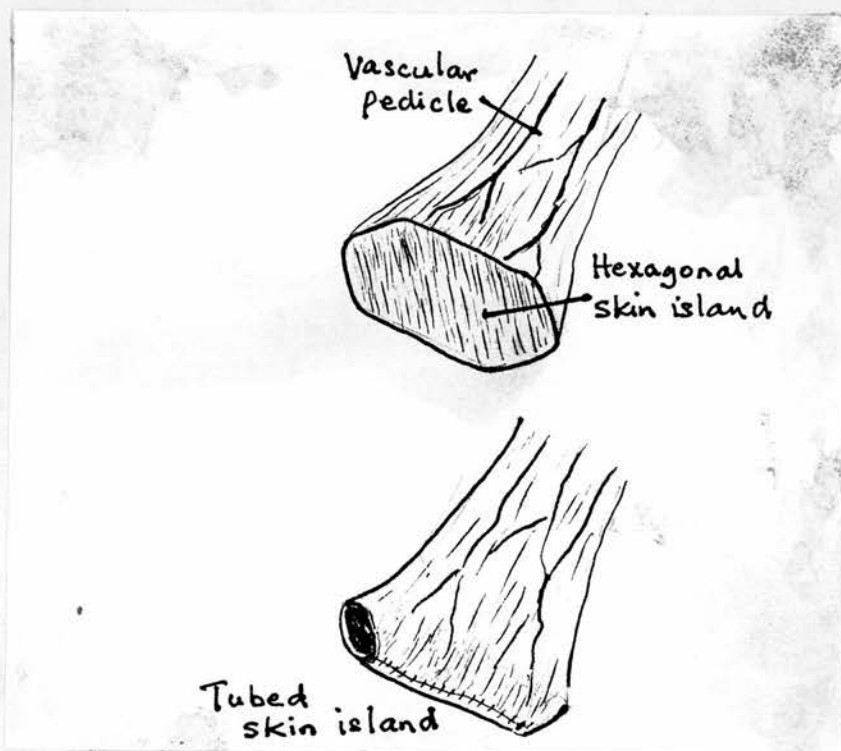


Fig. 28 Hexagonal skin island

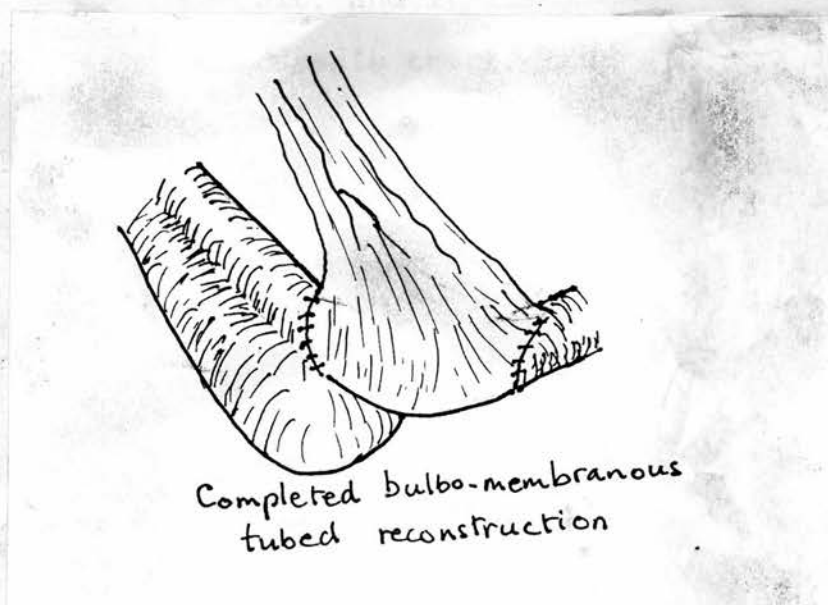


Fig. 29 Completed bulbomembranous anastomosis

The steps in the fashioning of the flap are the same as have been described for the patch urethroplasty, except for the shape of the island of skin.

The skin island may be tubed around a size 16Fr. Foley catheter, passed from the external meatus and through the urethral stumps into the bladder, before being anastomosed to the urethral stumps.

In bulbo-membranous urethral strictures, where the proximal urethral stump is almost at the apex of the prostate, the proximal suturing to get accurate skin to mucosa apposition can often be difficult, and it is more convenient to start the anastomosis there with the skin island on the flat. Next, the distal anastomosis is also performed, before the urethral catheter is passed from the external meatus and guided through the proximal urethrotomy into the bladder. The longitudinal tubing skin sutures complete the anastomosis.

Urinary Diversion

In impassable bulbous and membranous urethral strictures,

diversion of the urinary stream by means of a suprapubic cystostomy is considered mandatory.

Most of the patients initially come in with acute retention of urine, sometimes with chronic retention, and therefore already have a suprapubic cystostomy. Most have had their suprapubic cystostomy for many months, and some for several years.

When not present, a suprapubic cystostomy is performed at the beginning of the operation.

In penile and penoscrotal urethral strictures, when there is no prior suprapubic cystostomy, we have not found it always necessary to perform it initially, except in the presence of urethro-cutaneous fistulae and peri urethral abscesses.

Prophylactic antibiotics are given intravenously after induction of anaesthesia, usually an aminoglycoside like gentamicin combined with a penicillin derivative like ampicillin or amoxycillin, or one of the cephalosporins.

Postoperative management

Wound drains are removed in 2-4 days.

The urethral catheter is removed in 10-14 days and the patient asked to void through the urethra.

If there is any temporary leakage of urine from the reconstruction wound, urinary diversion is resumed, and the patient stopped from voiding per urethram for a few more days. If there is leakage, and there is no suprapubic catheter, the urethral catheter is re-introduced, and used for urine drainage.

If there is no urine leakage from the wound the patient is discharged home voiding per urethram, but with the spigotted suprapubic catheter still in position.

Check catheterisation with a 20Fr. Foley catheter is done weekly for 4 weeks, and if there is no tendency to stenosis as evidenced by free passage of the urethral catheter, the suprapubic catheter is removed.

Retrograde urethrograms, and urethroscopy are also used in follow-up assessments, but not as a routine, because of constraints on operating theatre time and radiological facilities.

Results

Flap survival

All the distal penile-preputial island flaps used for urethral reconstruction have survived, and there has been no loss. It is easy to judge the survival of the black skin used at urethroscopy, because of its contrast with the pink urethral mucosa. Fig.30.

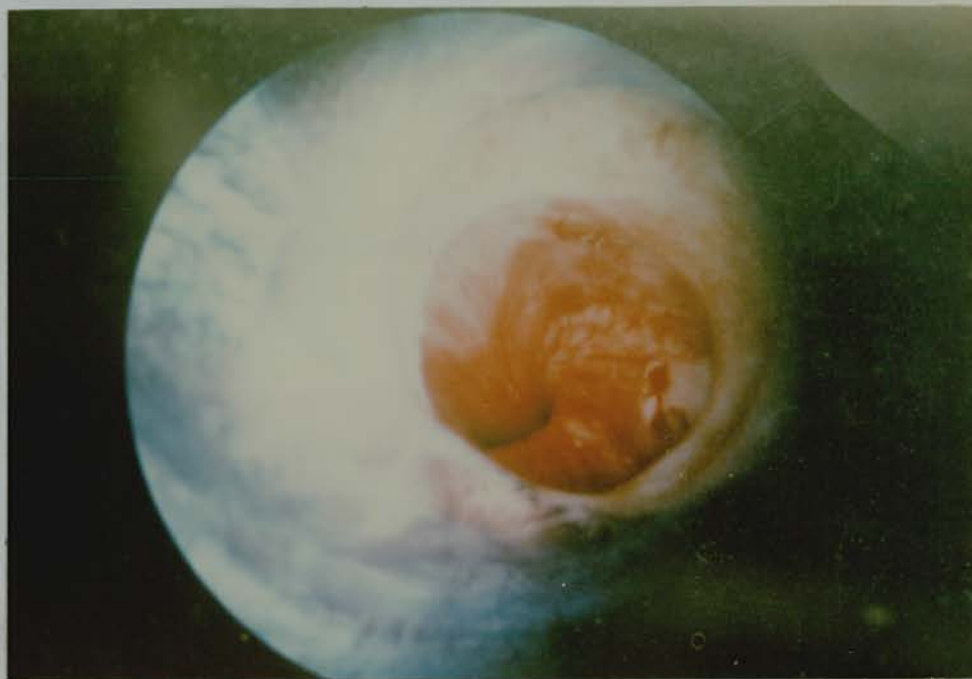


Fig. 30 Urethroscopic appearance of neourethra

Fistula formation

There was temporary leakage of urine through the reconstruction wound in about 20 per cent of patients on

first voiding, but the leakage stopped with further urine diversion in all except one case.

Stenosis and Restricture

There has been stenosis, usually at the proximal muco-cutaneous anastomosis or in urethra just proximal in about 10% of the bulbo-membranous urethroplasties, and restructure in another 5%.

Superficial necrosis of denuded skin flap.

The distal **part** of the skin-dartos unit **dissected off** the loose areolar **vascular** pedicle, and which is used to recover the shaft of the penis, sometimes turns purplish or bluish, especially at the **frenal corner**, and if unexcised, gives rise to **superficial** necrosis of the skin. This heals very quickly, **and does not** give rise to breakdown of the wound or scarring. The portion of the skin-dartos unit that turns bluish, should always be excised, **as there is** enough skin left for covering the penile shaft. **Fig.31** and **Fig.32**.



Fig. 31 Necrosis of denuded skin flap



Fig. 32 Necrosis of denuded skin flap

Diverticulum formation

Different grades of diverticulum may form in the skin island at the reconstruction site, Fig. 33:



Fig. 33 Diverticulum formation

CLITORAL ISLAND SKIN FLAP VULVO-VAGINOPLASTY IN FEMALE
PSEUDO-HERMAPHRODITES OF THE ADRENOGENITAL SYNDROME

In the female pseudo-hermaphrodite of the adrenogenital syndrome, the skin of the hypertrophied clitoris can be used as an island flap for the reconstruction of the distal vagina and introitus. Fig. 34.



Fig. 34 Female pseudohermaphrodite

Technique

A transverse or inverted-U incision is made in the perineum, and by means of a sound in the urogenital sinus, and dissection, the lower part of the vagina and its junction with the urethra are exposed, and separated. The urethra is then catheterised and the balloon inflated. The urethra may have to be extended by terminal reconstruction to bring it to its proper position. The anterior bridge of perineal skin is then divided in the midline up to the orifice of the urogenital sinus, Fig.35.



Fig. 35 Perineal dissection

A circumcising incision is made at the coronal sulcus of the glans clitoris, and the skin and vascular subcutaneous tissue dissected off the fascia clitoris (Buck's fascia) as a flap, Fig. 36.



Fig. 36 Elevated flap of skin and subcutaneous tissue

The skin-subcutaneous tissue flap is lowered over the clitoris, and a skin deep only incision made proximal to the base of the clitoris, and extended postero-laterally to the sides, outlining the clitoral skin as an island.

The skin lateral and superior to the skin island is dissected off the subcutaneous vascular pedicles containing axial branches of the right and left superficial (superior) and deep (inferior) external pudendal arteries, and the draining veins. Fig.37.



Fig. 37 Demarcation of clitoral skin island

A midline incision is made in the subcutaneous pedicle,

through which the clitoris and the urethral catheter are brought dorsal to the skin island. This incision may need to be extended to include the proximal margin of the island flap skin, to enable the urethral orifice to lie in its proper place, and not behind the flap, so that catheterisation would be direct and not angulated. Fig.38 and Fig.39.

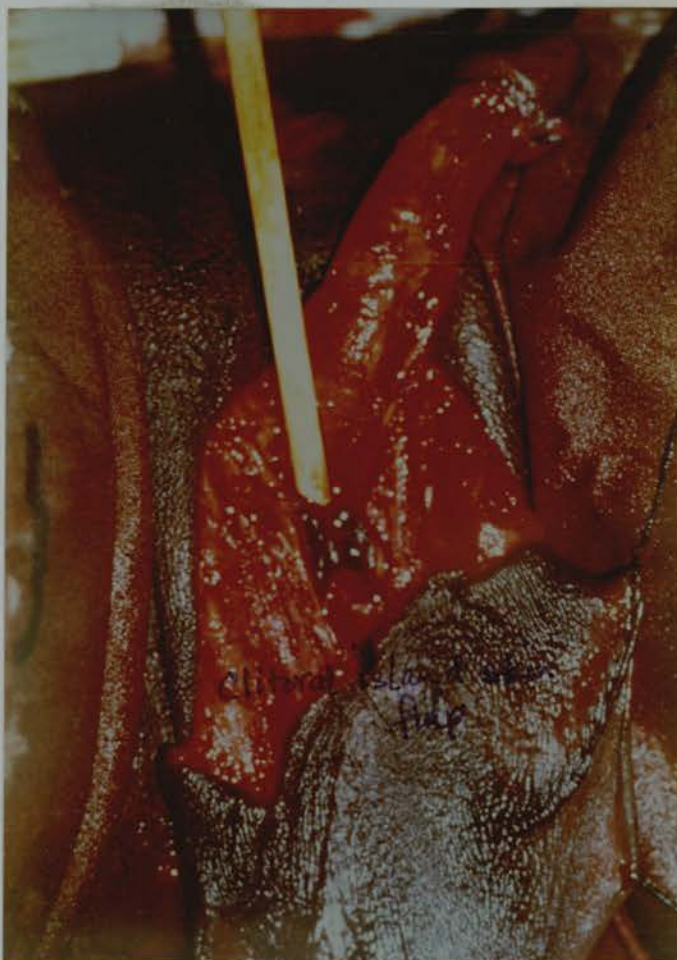


Fig. 38 Clitoris and catheter dorsal to flap



Fig. 39 Incised proximal margin of skin

The clitoral skin island is then inverted and its inferior free margin sutured to the divided edge of the vagina. Fig.40.

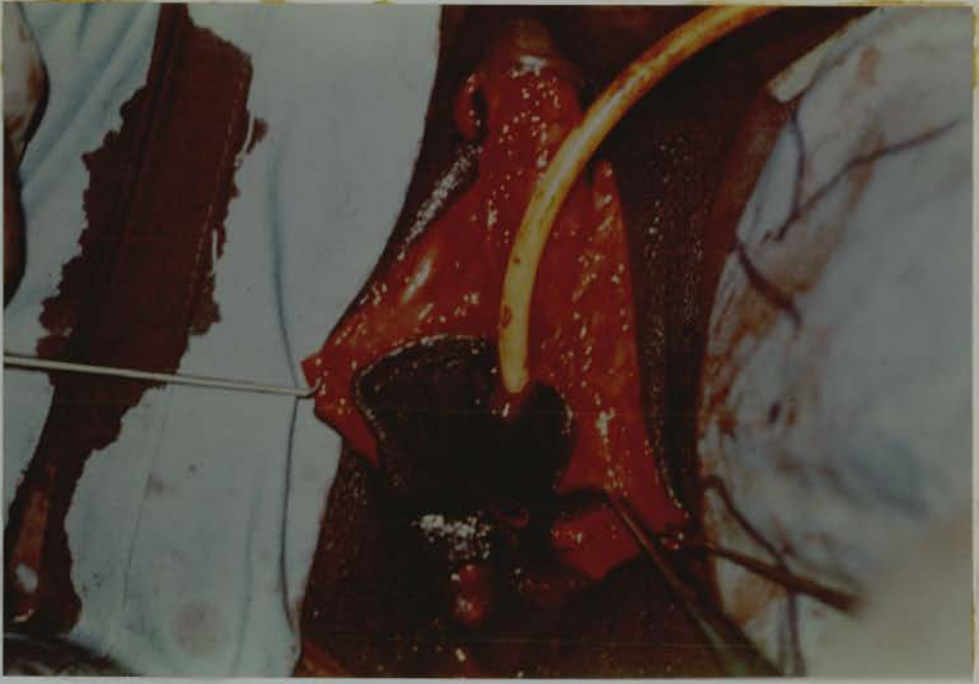


Fig. 40 Inversion of skin island into vagina

The glans clitoris, together with the dorsal neurovascular bundle, are dissected off the corpora cavernosa, which are traced as far down the crura as practicable and excised. Fig.41



Fig. 41 Glans clitoris and dorsal
neurovascular bundle dissected of
corpora cavernosa

The glans is reduced in size by wedge excisions from both infero-lateral sides, and is then anchored near the inferior border of the pubic symphysis, in its proper position. The now loose neurovascular ribbon is plicated at the edges and tacked down under the pubic skin. The glans was not reduced in size in this first operation.

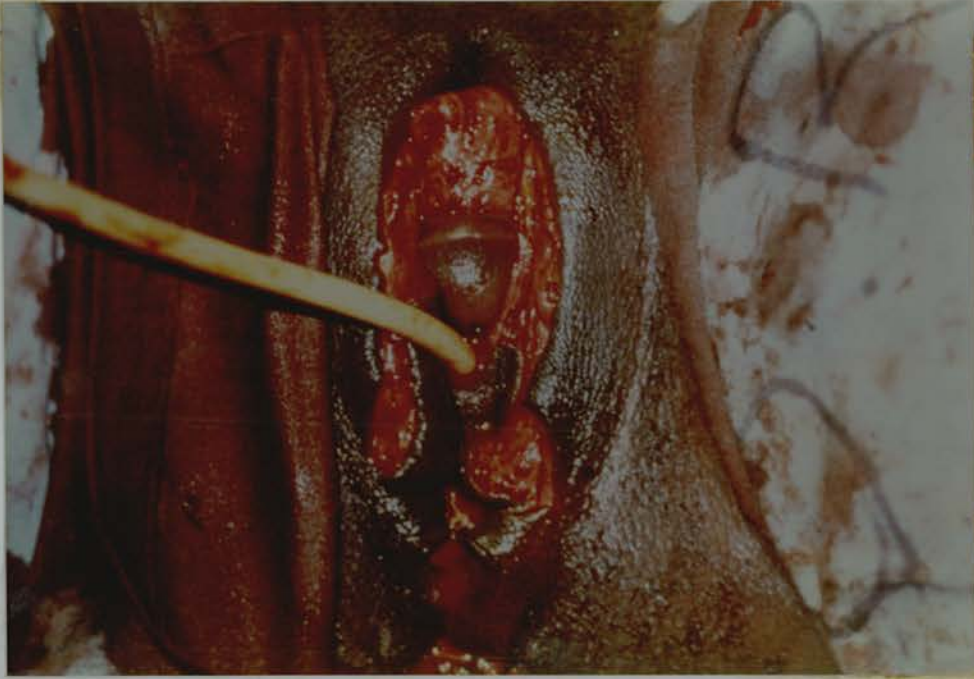


Fig. 42 Glans clitoris tacked down

The pink midline mucosa, which originally ran from the frenulum to the urethral orifice, together with a little strip of skin on either side, is now sutured back to the base of the reduced glans, and the scroto-labial and perineal skins closed around it, and around the margins of the new introitus, which is made up of the proximal, and now external margin of the clitoral skin island, Fig.43:



Fig. 43 Skin closure

Results

The patient when reviewed in 1988 1 year after surgery had an ample vagina, and there was no stenosis of the introitus.

CHAPTER 9

DISCUSSION

Anatomy

Until recently, very little had been written about the details of the blood supply of the coverings of the penis in the anatomic literature. This is not surprising, since Manchot's work on "The Cutaneous Arteries of the body" published in 1890, lay unnoticed till the 1960s and 1970s, inspite of the fact that surgeons were very much aware that skin survival, like all tissue, depended on its blood supply. It has been said that if the giants of plastic surgery in the 1930s, 1940s, and 1950s, had been aware of Manchot's published work, the development of plastic surgery would have been more rapid.

If the pattern of the blood supply of the skin of more obvious and prominent areas of the body did not receive much attention, it is no wonder that the blood supply of the skin or coverings of the penis received little or no attention.

Arterial Supply

Manchot in his publication (1890), writes that "the

descending branch of the superior external pudendal artery soon resolves into the terminal branches that participate in supplying a territory of skin involving the penis and the anterior portions of the scrotum." He does not elaborate on the pattern of the distribution in the penis, although his diagram gives an indication, Fig. 44:

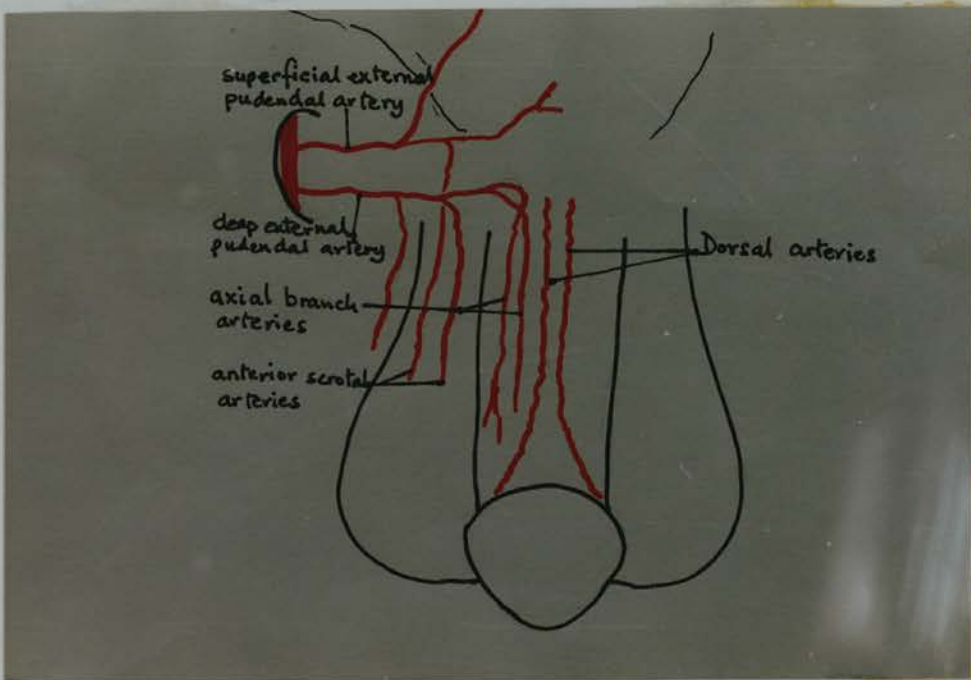


Fig. 44 Distribution of external pudendal arteries (Redrawn after Manchot)

Salmon (1936) appears to have been the first to describe in detail the terminations of the external pudendal vessels.

According to him, the superior and inferior external pudendal arteries had a common stem in about half his dissections. Manchot also mentions that the superior and inferior external pudendal arteries may occasionally arise from a short common trunk. We too have found this to be occasionally so, although in the majority of our dissections, both the superficial (superior) and deep (inferior) external pudendal arteries have been present, Fig. 8.

According to Salmon, quoted and supported by Juskiewenski et. al. (1982), the inferior external pudendal is the main artery of supply of the coverings of the penis, sending three or four collateral branches that run in the loose areolar subcutaneous tissue up to the prepuce, the superior external pudendal supplying small branches to the dorsum of the root of the penis only. In our dissections, we found that the superficial external pudendal artery often contributed significantly to the supply of the coverings of the penis, and in some cadavers it was dominant. The contributions of the superficial external pudendal arteries may be direct, when they end as the dorso-lateral axial branches, or supply the whole of the dorsum and considerable portions of both lateral sides of the penis Fig. 4, or indirect through anastomoses with branches of the deep external pudendals. These anastomoses may be early, soon

after their origins from the femoral artery, or late near the base of the penis, and from the pre-pubic or suprapubic arcade formed by the superficial external pudendal arteries of the two sides, Fig. 5.

The main point is that both the superficial (superior), and deep (inferior) external pudendal arteries make significant contributions to the vascular supply of the coverings of the penis.

I agree with Salmon that the main connections between the arterial plexus in the loose areolar subcutaneous tissue and the deep plexus of dorsal and circumflex arteries, is just behind the coronal sulcus, at the base of the prepuce, by means of perforators passing through the fascia penis, as can be seen at urethroplasty from the position of the main bleeding points. Along the shaft of the penis, these connections are fine, making it possible to dissect the subcutaneous tissue off the fascia penis without much bleeding. Occasionally the connections along the shaft are large. Jarow et. al. (1992) in discussing the misinterpretations of Penile Duplex Ultrasonography due to Arterial Anatomic Anomalies, noted that in 2 percent of their radiological examinations, there was a connection between the external pudendal and cavernosal arteries.

The main connection between the arterial plexus in the loose areolar subcutaneous tissue, and the subdermal (subdartos) arterial plexus, is at or near the base of the penis, where the branches feeding the subdermal plexus come off the axial penile branches of the external pudendals. Again, connections between the two plexuses are fine and tenuous along the shaft of the penis, except occasionally when they may be large.

This proximal main connection, means that the distal part of the skin that is dissected off the subcutaneous vascular pedicle in distal penile-preputial island flap urethroplasty, may have a poor arterial blood supply, especially if the dissection has been too close to the dartos layer to damage the subdermal vascular plexus. This explains the distal superficial skin necrosis that occurs in the "denuded" skin in the early postoperative period. This necrosis does not disrupt the healing of the penile wound, and epithelializes quickly without scarring.

According to Hinman (1991), the arteries supplying the prepuce do not terminate at the preputial ring, but "loop back upon themselves to terminate at the corona. Fig.45 and Fig. 46:

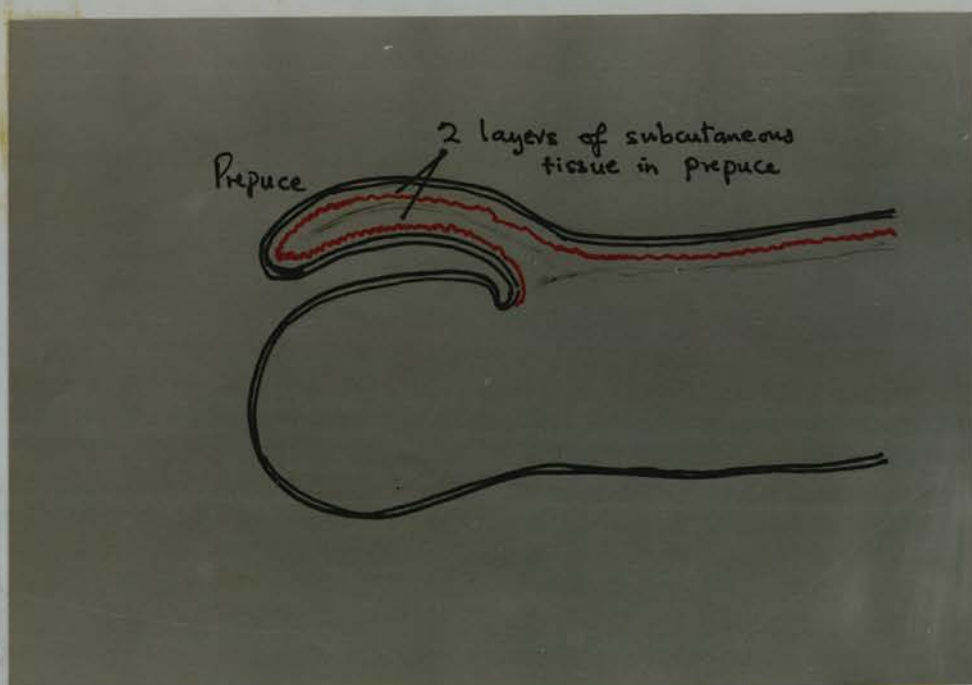


Fig. 45 Redrawn after Hinman

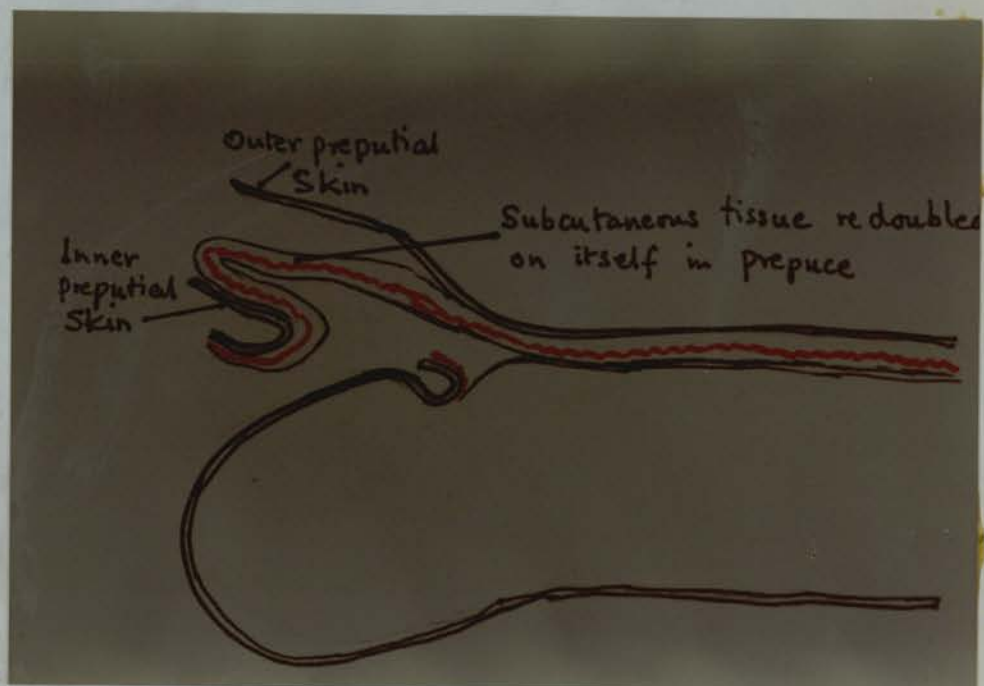


Fig. 46 Redrawn after Hinman

His description and diagram seem to portray the pattern of the subdermal (subdartos) vascular plexus that nourishes the skin, and not that of the axial branches of the external pudendal arteries running in the loose areolar subcutaneous tissue, which forms the vascular pedicle in all the different penile preputial island flap urethroplasties described. His contention that the inner surface of the prepuce has the poorest blood supply is contrary to the observations of most who have studied the blood supply of the coverings of the penis, and to the success of urethroplasties employing islands of the inner preputial skin (Duckett, 1992, Hinman, 1991: Editorial comment by Hodgson).

In dissections of the prepuce in the fresh cadaver, I have seen fine long arteries given off the subcutaneous axial artery, before it enters the prepuce, and passing directly to the inner and outer preputial layers, Fig. 47 and Fig.48:

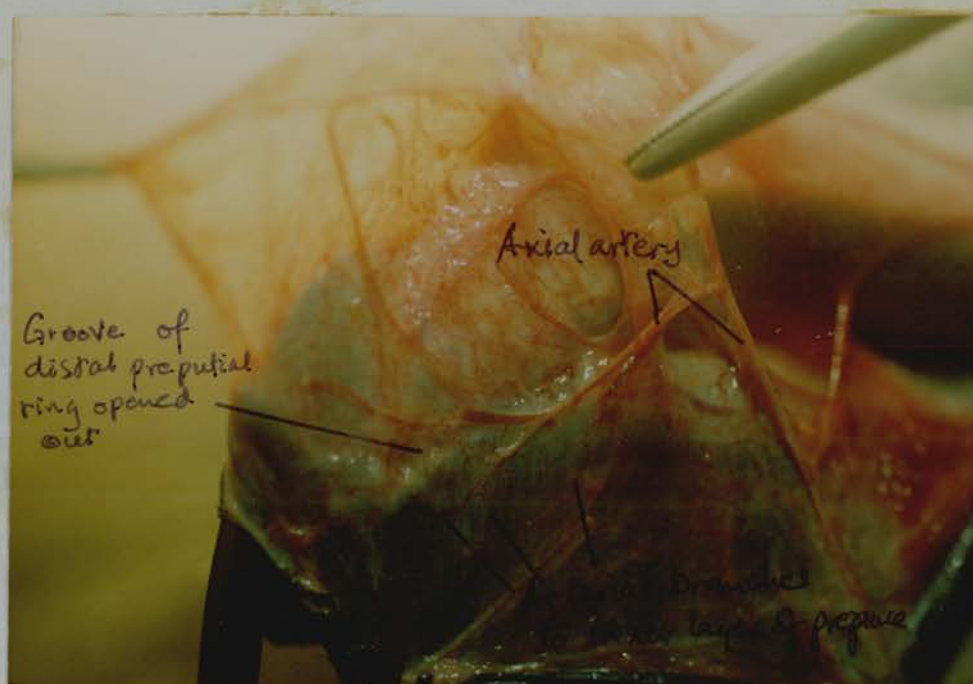


Fig. 47 Inner preputial branches of axial artery

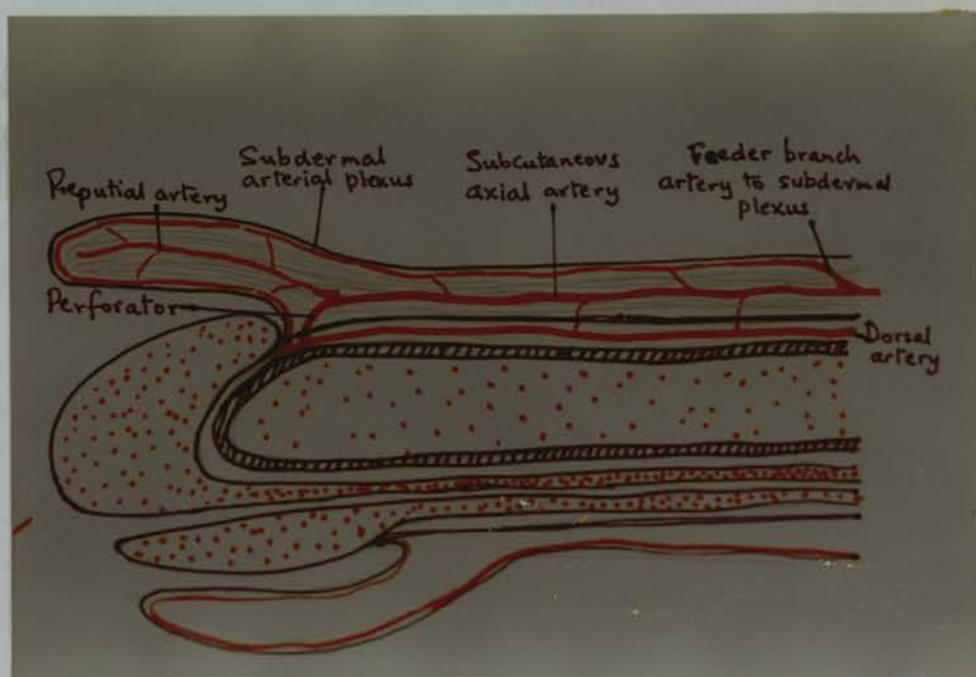


Fig. 48 Preputial skin branches (Schematic)

When the skin island has been isolated, attached to the vascular subcutaneous pedicle, the normal tenuous connections between the blood vessels in the pedicle and the subdermal vascular plexus open up to feed it.

The deep (inferior) external pudendal artery receives its name "deep" because it is said, classically, to run a deep course from its origin, across the pectineus and adductor longus muscles, sometimes passing behind the adductor longus, to enter the superficial fascia at its medial border.

Salmon (1936), comments that it is only when the superior (superficial) and inferior (deep) external pudendal arteries arise from a common stem, that the "deep" artery runs a superficial course. I have noticed in many cadavers the deep external pudendal artery run a superficial course, even when there is a separate superficial external pudendal artery. Perhaps this is the reason why the French anatomists use instead, the terms "superior" and "inferior" external pudendal arteries.

Venous drainage

Most anatomy books describe only the superficial dorsal median vein or veins. In fact, in many of the penises I have observed, both in cadavers and in live patients, there are also large visible lateral veins, which may

sometimes be dorso-lateral or ventro-lateral.

According to Gras (1902), all the tributaries of the superficial dorsal median vein come from the prepuce, from a venous arch at the tip, which form two trunks along the inferior aspect of the penis. These two trunks, one on either side, progressively run around the lateral aspects of the penis, and finally unite at the junction of the middle and posterior thirds, to form the superficial dorsal median vein. He says that the preputial ring also receives veins originating from the deep system.

According to Sappey (1888), however, both the superficial and deep dorsal median vein or veins arise from the retrobalanic plexus of veins, so that, when they emerge from behind the glans, they are already large in size. Pernkopf (1983) also depicts the superficial and deep dorsal median veins originating from the retrobalanic plexus of veins. The superficial dorsal median vein, after piercing the fascia penis to gain the superficial layers of the loose areolar subcutaneous tissue, is joined by the small preputial tributary veins, and not the other way round.

As mentioned earlier on, the large independent communicating veins seem to be riding on the surface of

the loose areolar subcutaneous tissue.

The French anatomist Victor Gras, in his Thesis of 1902 entitled "Anatomic Research on the Veins of the Penis" writes

"We have found it (the loose cellular layer) always to be composed of two sheets that are easily separated by the blunt end of the scapel. The two sheets, a superficial and a deep, enclose between them a cavity or space in which run numerous veins that connect the superficial dorsal to the deep system. Within the cavity also run nerve and arterial branches.

The presence of the vascular and nerve structures between the cellular sheets, supports the anatomical concept of a serous cavity surrounding the penis. One of the walls of this serous cavity is a visceral layer applied to Buck's fascia, and the other, the parietal layer lining the deep aspect of the skin and the peri-penile muscle of Sappey.

The superficial dorsal vein always runs between the skin and the parietal layer." (Translation from French text)

Full Thickness Skin Grafts

Full thickness skin grafts harvested from the prepuce or penis, or some other non-hairy site such as the medial side of the upper arm, have been successfully used for substitution urethroplasty.

These survive initially by imbibition of nutrients from the surrounding tissues, before developing their own blood vessels.

Skin Flaps

The most important consideration in the use of skin flaps in reconstruction, is the preservation of the blood supply. A knowledge of the pattern of distribution of the blood vessels is therefore most important in the planning of the flap.

Numerous urethroplasty techniques have been described in the past 150-200 years, based on the use of skin flaps in reconstructing the urethra in hypospadias and in urethral stricture. The multiplicity is an indication that most of them have had problems, which, in my opinion, have been due to inadequate knowledge of the pattern of the blood supply, and its relation to the layers of the coverings of the penis.

Coverings of the penis

As discribed earlier, there are three important layers of the coverings of the penis, the skin-dartos layer with the subdermal (subdartos) vascular plexus nourishing it; the loose areolar subcutaneous tissue containing the axial branch arteries with their venae comitantes, and the independent veins; and the fascia penis.

The two relatively bloodless and easy planes of cleavage are between the skin-dartos unit and the subcutaneous vascular tissue, and between the subcutaneous tissue and

the fascia penis, so that all dissection should be in these planes to preserve the blood supply.

The Duplay I and other similar techniques created a neourethra in distal penile hypospadias, by making a tube from a distal median strip of ventral skin incorporating the hypospadiac meatus at its proximal end. This involved two lateral, and a proximal, skin incisions. The undermining of these lateral incisions to enable conversion of the skin strip into a tube, involved the cutting off of the main blood supply coming from the subcutaneous tissue.

Most of the problems with the buried skin strip technique of Duplay II, Denis Browne and Johanson, in my view, stemmed from dissection within the loose areolar subcutaneous tissue while raising the lateral skin flaps, which destroyed the blood vessels. This resulted in diminished vascularity of the edges of the lateral skin flaps, with later necrosis and fistula formation. Denis Browne (1949), in his paper on Hypospadias, when describing the raising of the lateral skin flaps in the buried skin strip technique of urethroplasty, writes on page 371, and I quote:

"The skin flaps are raised widely on either side by divulsion with blunt scissors, so that they can fall together quite loosely with about an inch to spare: there must not be the slightest suspicion of tension on the joining flaps. A considerable amount of haemorrhage occurs during this process, but I think it is inadvisable

to ligature any but the large and obvious bleeding points. Attempts to gain a perfectly dry field waste time, and we are apt to fill the wound with catgut and damaged tissue. I have never known the bleeding to cause anxiety."

Many of us must have had the same experience in past years, and that was because we were elevating the skin flaps, not in the plane of cleavage between the loose vascular subcutaneous tissue and the fascia penis, but in the subcutaneous layer itself, thus damaging the blood vessels.

Those surgeons, who learned, in raising the lateral flaps, to dissect in the plane between the subcutaneous vascular tissue and the fascia penis got better results, because they preserved the blood supply. Fig.49.

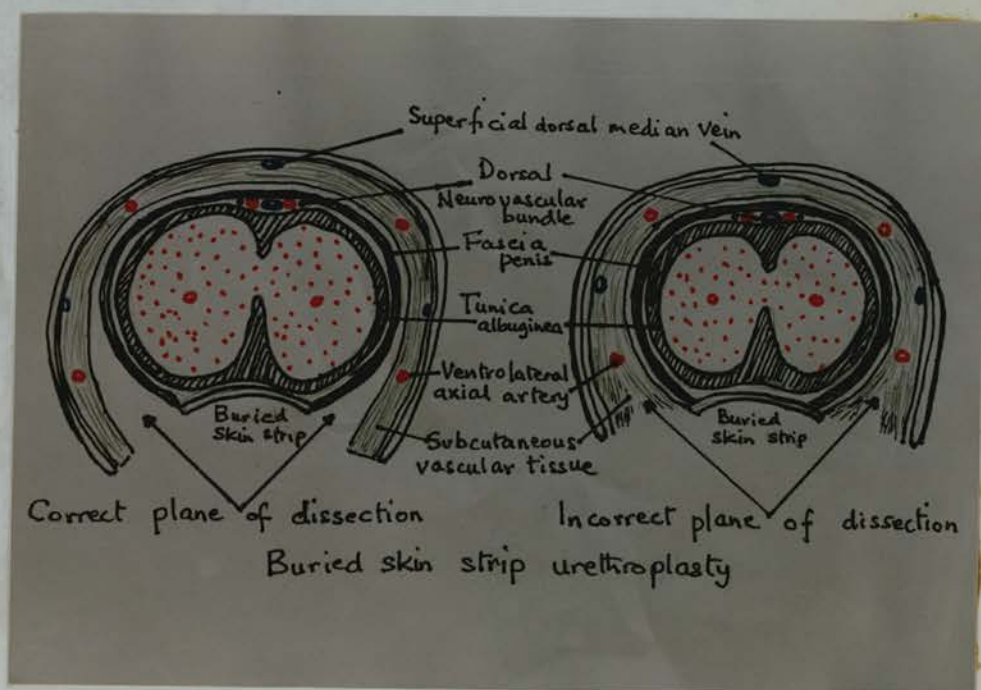


Fig. 49 Buried skin strip urethroplasty

In the flip-flap type of operation of Ombredanne, and Devine and Horton, and also the distally based tube flap of Mathieu, and Mustarde, the proximal flap that was flipped to the tip of the glans, or tubed and turned over to the glans, would be deprived of most of its blood supply by the lateral and proximal incisions, and the dissection off the fascia penis to flip them over distally.

Since the better appreciation of the pattern of the blood supply, the lateral incisions have been made only skin deep, and by dissecting laterally between the skin-dartos unit and the subcutaneous vascular tissue, and in the midline, from the proximal edge of the skin flap towards the hypospadiac meatus, between the subcutaneous tissue and the fascia penis, it has been possible to preserve the vascularity of the flap, and at the same time make it mobile enough to be flipped over to the tip of the glans, as a flat sheet patch, or as a tube. Fig.50:

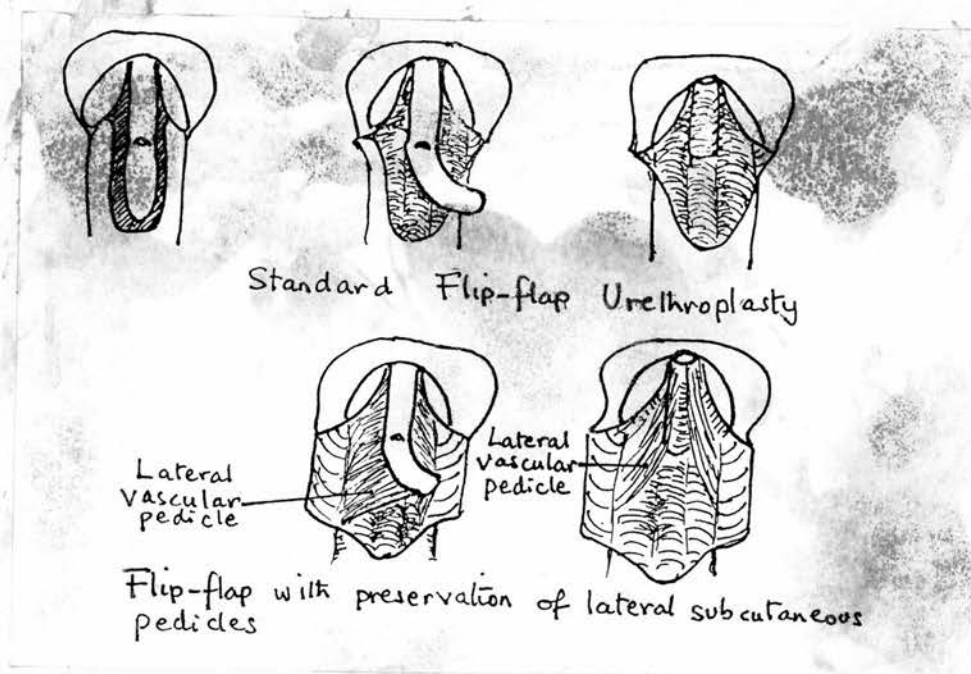


Fig. 50 Flip-flap urethroplasty

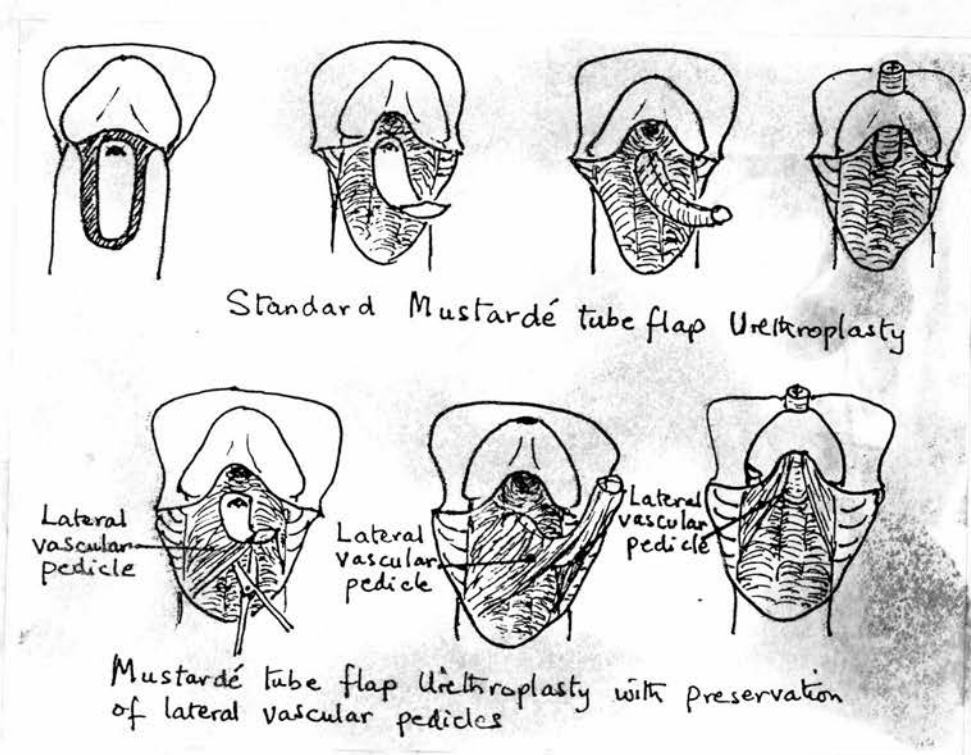


Fig. 51 Mustarde tube flap urethroplasty

In a personal communication, Devine C.J. Jr. and Jordan G.H., have both informed me that the complication rate of the flip flap and Mustarde urethroplasties, have been considerably reduced with the preservation of the lateral vascular subcutaneous pedicles.

The success of The Orandi (1968) local penile flap for urethral reconstruction in stricture, also depends for its success on the preservation of enough vascular subcutaneous tissue with the skin.

Byars (1955) Broadbent et.al.(1961), Des Prez et. al., (1961), Hodgson (1970), and Asopa (1971) all used flaps of one layer of preputial skin still attached to the other layer, and to the vascular subcutaneous tissue for their blood supply.

Hinderer's (1968, 1986) tunnelization urethroplasty for hypospadias incorporated the hypospadiac meatus proximally in an oblique strip of ventrolateral skin that was extended distally to include part of the prepuce, which was tubed to reconstruct the distal urethra.

According to him,

"...The skin proximal to the meatus and lateral to the flap is dissected ... at a very superficial level.....to preserve all the subcutaneous tissue and the vascularization of the flap of the neourethra."

The technique, in a way, is a modification of the Duplay

I principle, with extension of the skin strip to include the prepuce, and with preservation of the blood supply.

Standoli (1977) and Duckett (1980) for hypospadias, and Quartey (1983) for urethral stricture used transverse islands of preputial or distal penile skin with a subcutaneous vascular pedicle which may extend to the base of the penis, and which would enable any part of the urethra to be reconstructed.

The use of a transverse island of prepuce or distal penile skin ensured a relatively hairless neourethra. Duckett's and Quartey's inner preputial islands are definitely hairless, but Standoli's outer preputial skin island, and Quartey's distal penile skin island may have fine lanugo hairs on them.

Hinderer (1975) used a longitudinal island of penile skin, which came down almost to the base of the penis on a vascular subcutaneous pedicle in hypospadias in children, and the proximal part of the neourethra in adulthood may contain coarse hair.

Complications of Substitution Urethroplasty

The complications of substitution urethroplasty which apply to all known techniques are:

1. Fistula formation

Although Duckett (1992) thinks it is due to not achieving a water-tight anastomosis, it is more likely due to localised necrosis of skin at the sites of anastomoses, the result of tight suturing.

2. Stenosis and restricting at the anastomotic sites.

This is due to technical faults in not achieving accurate skin to mucosa apposition, and in my experience has usually occurred in the prostato-membranous area, where suturing is often difficult. Lack of sutures with needles of appropriate size, curve, and strength can be disheartening, and the many attempts tends to cause tearing and fraying of the urethral edge. The latest aid, which has come out in the last year or two, is a posterior metal sound with longitudinal grooves at its curved end, so that when passed down the prostatic urethra from the bladder into the proximal stump of membranous urethra, sutures can more easily be inserted at the sites of the grooves. The latest version has levers, which spread out the end of the

proximal urethral stump. All this is evidence of the difficulty experienced in suturing.

Some surgeons, in discussions, have ascribed the stenosis and restructure to the formation of hypertrophic scars, especially in the black skinned race, but the prepuce does not form hypertrophic scars, and in our postoperative urethroscopies, we have not found any evidence of this. The fact that in the same patient the distal anastomosis is normal and of adequate calibre, and the proximal anastomosis is stenosed or strictured, does not support this theory.

3. Stenosis and restructure proximal to the proximal membrano-urethro-cutaneous anastomosis in reconstructed membranous neourethras.

Re-stricture and stenosis have been found in some patients proximal to the proximal muco-cutaneous anastomosis near the apex of the prostate. The probable explanation for this is the dilatation of a stricture or stenosed area while locating the proximal end of the membranous stricture with a posterior sound.

This goes unnoticed at the time of operation. In the neourethra the black skin is obvious, and the stenosis in the pink urethral mucosa more proximally is also obvious at urethroscopy, and at reoperation for restructure, Fig.52:

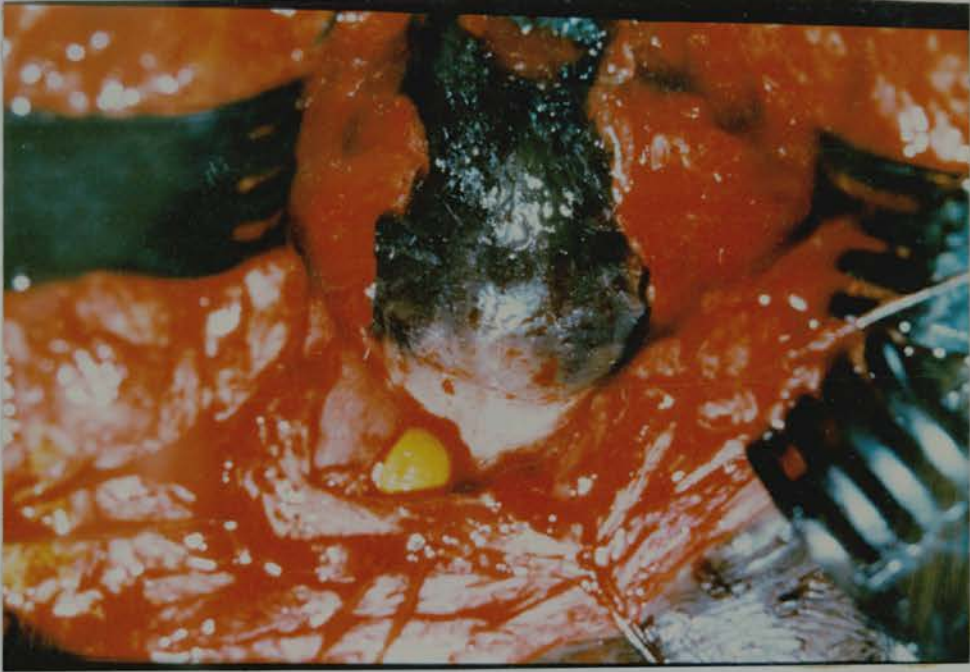


Fig. 52 Black skin of neourethra seen at reoperation

Hodgson (1981) has said that:

"Hypospadias complications are a result of impaired healing from tissue death, infection, or malalignment. These occur less frequently with vascularized flaps."

We have successfully used distal penile-preputial island skin flaps for urethroplasty

in stricture, in one-stage, combining it with excision of periurethral abscesses and urethro-cutaneous fistulae.

4. Diverticulum formation

This may be the result of using too large an island of skin in the urethral reconstruction, usually when it is a patch reconstruction. The occurrence of a distal stricture, such as a meatal stricture in hypospadias repair, may, by causing increased intraurethral pressure proximally, contribute to diverticulum formation. Even when the skin has been put on the stretch in marking out the island, it turns out to be larger when cut, because of the elasticity of the skin.

Clitoral Island Skin Flap Vulvo-Vaginoplasty

Hinderer (1979) had successfully used the one-stage clitoral island skin flap technique of vaginoplasty in 8 female pseudo-hermaphrodites.

Meyer and Kesselring (1980) reconstructed the vagina with a penile skin island flap in a male transsexual.

Without any previous knowledge of the work of Hinderer, and Meyer and Kesselring, Quartey, Kurtzmann and Brumskine (1987) performed a clitoral island flap vaginoplasty similar to Hinderer's, in a female pseudo-hermaphrodite.

The skin island from the hypertrophied clitoris seems to produce a ~~much~~ better terminal vagina and introitus, than the perineal skin flap or skin grafts in general use, both cosmetically, and functionally, and without stenosis of the introitus.

Devine, Jordan and Schlossberg (1992) feel that the penile skin inversion vaginoplasty in male transsexuals produces too shallow a neovagina, and so prefer using the sigmoid colon.

The basic principle of the use of the clitoral or peno-preputial skin island flap for vaginal reconstruction is sound, both anatomically and clinically, and deserves greater attention. If the existing vagina is too small in the female pseudo-hermaphrodite, or the penis too small in the male transsexual to produce a deep enough vagina, a sigmoid colon segment can be added. That would cause less mucus secretion, than in a vagina made completely with sigmoid colon.

CONCLUSION

A. Although it was known that the skin and coverings of the penis are supplied by the superficial (superior), and deep (inferior) external pudendal arteries, this study has established that:

1. there are basically 4 axial branch arteries of the superficial and deep external pudendal arteries; right and left dorsolateral and ventrolateral, which run in the loose areolar subcutaneous tissue from the base to the end of the penis and prepuce, supplying the coverings;
2. there is a wide variation in the contribution of each of the two arteries - the superficial and the deep external pudendal arteries -, to the blood supply of the coverings of the penis, but that both contribute significantly.
Although the deep external pudendal artery is more often dominant, the contribution of the superficial external pudendal artery is not negligible, and sometimes is dominant;
3. the connection between the subcutaneous

arterial plexus and the subdermal (subdartos) plexus is mainly at the base of the penis, and that between the subcutaneous plexus and the deep arterial plexus formed by the dorsal and circumflex arteries, is mainly distal just behind the coronal sulcus.

- B. In the venous drainage there are large superficial dorsolateral, lateral or ventrolateral independent veins in addition to the superficial dorsal median vein normally described.
- C. There are two definite planes of cleavage in the coverings of the penis, in which dissection is relatively bloodless;
 - (a) between the skin-dartos unit, and the loose areolar vascular subcutaneous tissue and
 - (b) between the vascular subcutaneous tissue and the fascia penis.
- D. In urethroplasty for hypospadias and urethral stricture, the use of vascularised skin flaps in a one stage reconstruction, is becoming accepted as the optimum goal.

A knowledge of the pattern of the blood supply of the skin is important in the design of skin flaps.

Every surgeon who embarks on reconstructive surgery of the lower urinary and genital tracts, should therefore be conversant with the pattern of the blood supply of the coverings of the penis, and the planes of cleavage and dissection.

This knowledge of the anatomy of the blood supply and layers of the coverings of the penis, and the necessity to preserve the vascular subcutaneous tissue has improved the results of urethroplasty techniques like the flip-flap operation of Mathieu, and Devine, the tubed flap of Bevan, and Mustarde; and the buried skin strip method of Browne, and Johanson. This knowledge should enable surgeons to be more flexible in the design of their flaps.

It is appropriate to end by quoting Conway once again:

"Detailed knowledge of the vascular anatomy of the arterial circulation of the skin and subcutaneous tissue, is of practical importance to the reconstructive surgeon, who must form and transplant pediculated flaps the viability of which depends on this vascularity".

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